SIMPLE TRANSPARENT RADIOMODEM FOR THE 10 GHZ MICROWAVE BAND

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Some legacy systems require remote management using traditional communication interfaces such as RS-232. The communication flow is low-speed so the use of complex spread spectrum wireless equipment, based on IEEE 802.11, is unduly. The use of microwave bands allows high distance coverage between end point stations with relatively low transmission power. The efficiency of the antennas for the microwave band is very high so the antenna gain is very high compared to the low-frequency bands.

This paper presents a low-cost simple radio modem for the 10 GHz band, which uses narrowband FSK technology for transmission.

Suitable applications for this design cover a wide range of industrial systems for remote management and control. For example remotely control of traffic lights systems, control and management of dam lakes pumps, etc. The use of narrow-band FSK requires very small bandwidth, which is important for the licensed bands.

Key words: Microwave, Wireless, Radio modem, Gunnplexer, RS-232

1. INTRODUCTION

Previous successes using 10GHz gunn diode oscillators as local oscillators and transceivers for narrowband weak signal work [1], brought to mind the possibility of using these inexpensive units for higher speed digital data transmission. In addition to being inexpensive, these units - which are commonly used for motion detection (door openers and burglar alarms), speed measurement (police radar guns), and microwave receivers (radar detectors) - have all of the microwave circuitry self-contained. This is important because it makes the equipment more attractive to non-microwave users. The system block diagram in figure 1 shows the operating principles.

The two ends of a link operate "split." One transceiver oscillator typically operates on 10.53392 GHz, while the other end is 433.92 MHz lower, on 10.1 GHz. The difference between the two transmitter frequencies corresponds to the receiver first IF frequency. The receiver first IF on each end is generated when the remotely transmitted signal (frequency modulated by the data to be transmitted) is mixed with the local transmitter. Each end use its own transmitter as a receiver local oscillator, and each unit transmits continuously. Therefore, each receiver sees the same IF. This is the same full duplex arrangement used for many years by Amateur microwave enthusiasts. The transmitters run from 5mW to 10mW of output power depending of the gunn diode type. The transmitter is frequency modulated as its bias supply is varied and the frequency/voltage dependency of the gunn diode is used for tuning.

This same technique was used previously to phase lock such oscillators. The 60 cm dish used in this design has a gain of about 33 dB, or 2000 times at 10.5 GHz. When driven by the microwave transceiver, the effective radiated power (ERP) is about 10 up to 20W and is the same as that of a 10-watt 2-meter band radio driving a quarter-wave whip. We selected 433.92 MHz for the receiver first IF, with provision for tuning +/- 10 MHz to accommodate differential frequency drift with time or temperature of the free-running microwave transceivers. Using an IF in this range also lets you do some simple troubleshooting and testing with commonly available commercial FM 433MHz ISM receivers. No correction is necessary if both ends drift in the same direction because the IF doesn't change. Automatic Frequency Control (AFC), implemented by tuning the first IF nominally at 433.92 MHz, is provided to keep the transceiver tuned correctly. This conversion produces the second IF at the point, where detection takes place at 10.7 MHz in a Microchip rfRXD0420 FSK receiver chip [3]. This chip is specified to operate at data rates up to 80 Kbps per second.

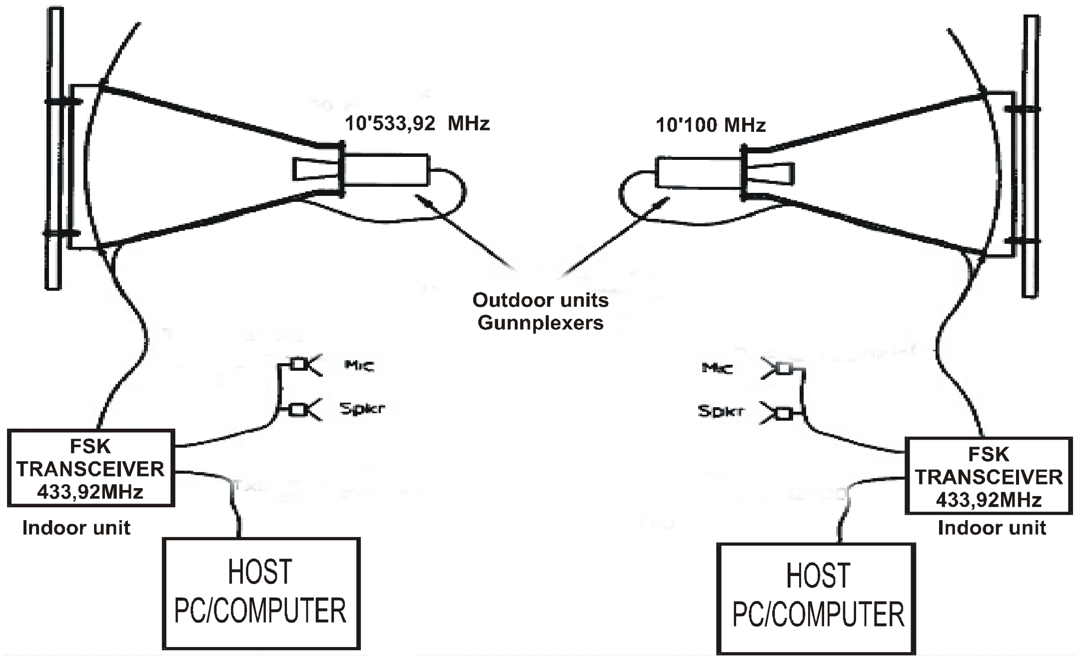

Figure 1 – System diagram

2. TRANSCEIVER MODULES

The structure of transceiver is shown on figure 2. The design looks very complicated, but in fact it is implemented on 3 low-cost integrated circuits (IC) and 2 special purpose diodes (a gunn diode [5] and a microwave mixer diode). The use of 2 intermediate frequencies (IF) and signal filtering stages ensure very good sensitivity.

The transceiver acts like a transparent modem. That means it bridges the serial interfaces directly without using special control (AT) commands. The data that comes to the RS232 interface is buffered. A flow control is supported by the modem using the RTS/CTS signals. The main processor forms a packet for transmission, when the buffer gets full. Transmission can be started if the data in the buffer did not reach the optimal size. That happens when a specific timeout occurs.

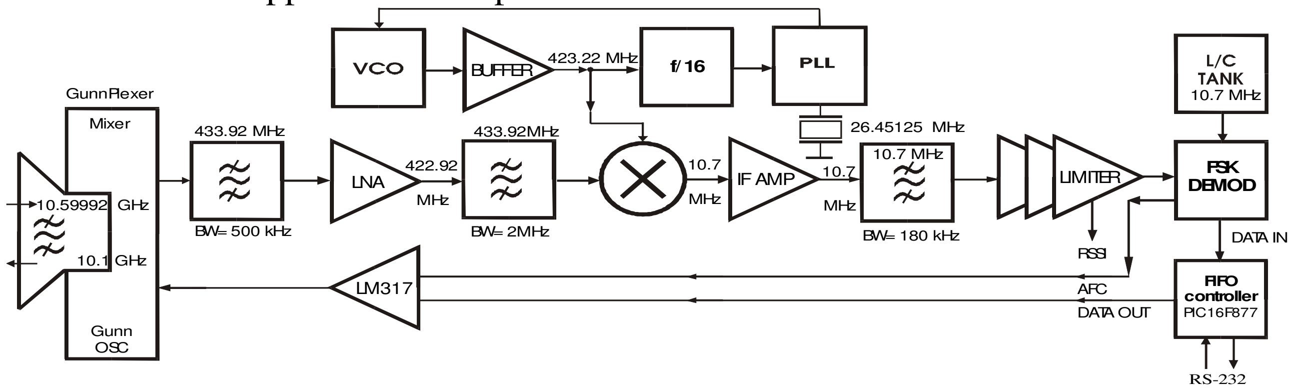

Figure 2 – Transceiver high-level diagram

2.1. Audio channel

We added the audio channel as an afterthought. It provides for human communication, particularly while debugging the link and operating it with digital data the first time. An electret microphone produces the audio signal for the transmission. The signal is amplified and limited also filtered by high and low pass filters before modulating the transmitter. Levels were selected to provide only small deviation compared with that of the digital channel. This allows the audio channel to operate without significantly interfering or degrading the digital data. A volume control and speaker amplifier sufficient for driving headphones or a small speaker are provided on receive.

2.2. Main Microcontroller

Design uses a low-cost microcontroller from Microchip as main processor for the modem. The microcontroller is PIC16F877A [2] and integrates ADC and UART modules. The UART module is used for the intercommunication with the host. Microcontroller is based on high performance RISC architecture. Working on 20MHz it is able to supply 5MIPS. Also it has in-build 4K-program memory and 384 bytes of RAM memory. Two of the ADC inputs are used for the RSSI and AFT measurement, while another one measure the current value of the voltage that supplies the generator gunn diode.

2.3. RF part and modulator

The rfRXD0420 [3], manufactured by Microchip is low cost, compact single frequency short-range radio receiver requiring only a minimum number of external components for a complete receiver system. The rfRXD0420 covers the receive frequency range of 300 MHz to 450 MHz. The rfRXD0420 can be configured for Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), or FM modulation. The rfRXD0420 is compatible with rfPIC™ and rfHCS series of RF transmitters. Functional diagram of the receiver is shown on figure 3.

Modulator consists of linear regulator LM317, which supplies the gunn diode. The loop back input of the regulator is used for the modulation input. Thus ensure voltage variation at the power supply, which comes to drive the gunn diode proportional to the modulation signal. The variations of the gunn diode supply ensures frequency offset (frequency modulation) in the frequency generated by the gunn diode. Circuit diagram of the modulator and AFT sections is shown on figure 4.

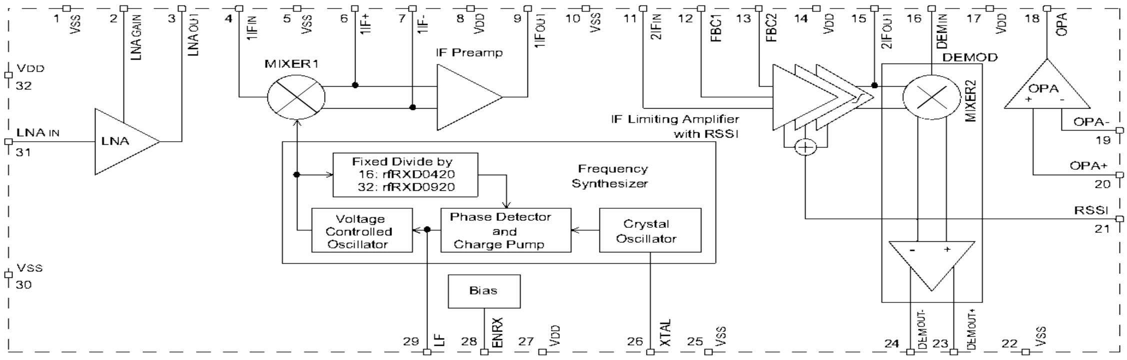

Figure 3 – Receiver functional diagram

Automatic frequency tuning process acts directly to the modulator to compensate temperature frequency offset. Because of the continuously work of the both transceiver modules the intermediate frequency of 433.92MHz is always available in both receivers. The automatic correction of the frequency is made in one of the units. It is enough to make the first intermediate frequency steady. The correction from one side compensates the frequency drift from the other side of the link because instability of the TX frequency in both modules cause first intermediate frequency instability, which is the same for both modules.

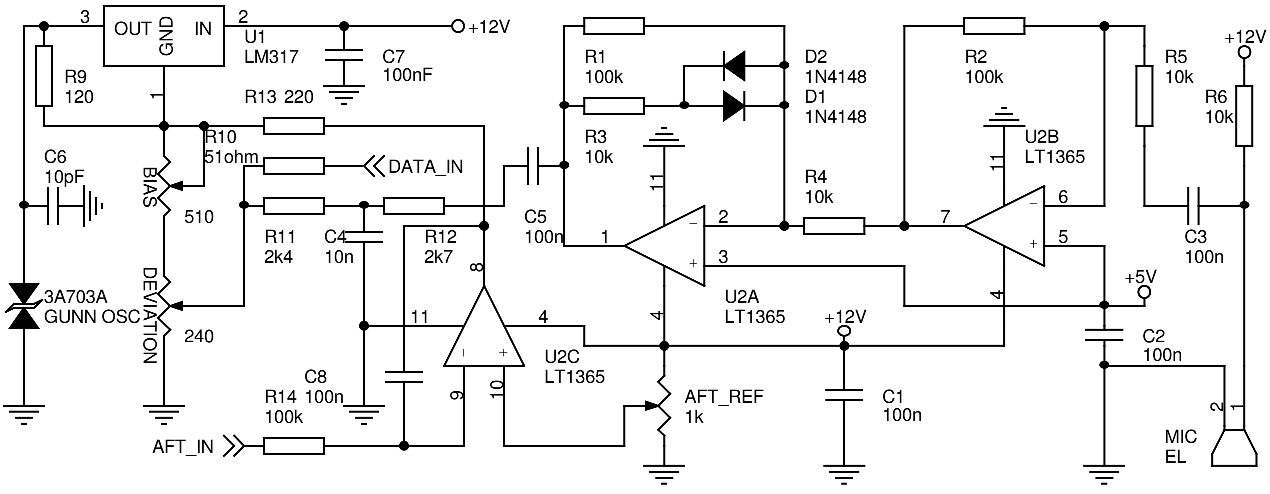

Figure 4 – Modulator circuit diagram

2.4. Microwave part and Gunnplexer

The outdoor unit consists of 60 cm parabolic antenna and a gunnplexer [4] module. The gunnplexer module is a mechanical construction shown on figure 5. It has two sections; one is for the mixer diode near the open end focused to the parabolic antenna and a generator gunn diode [5] in the closed section. The gunn diode is AA703A or 3A703A . It acts as generator that supplies the RF power to the antenna; also it acts as local oscillator for the mixer diode in front of the generator diode. Mixer diode is a microwave mixer diode.

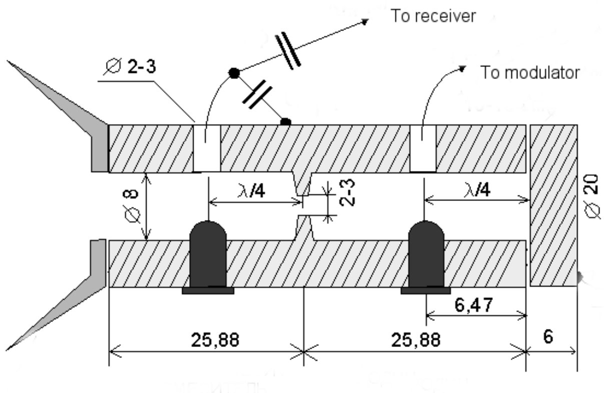

Figure 5 – Gunnplexer construction

We used Д605 for the mixer diode. At the output of the mixer diode comes the first intermediate frequency, which is about the difference between generator diode frequency and the reception frequency. In our case the first intermediate frequency is 433.92MHz.

3. GOALS IN THE PROJECT

Fortunately, microwaves and high-speed communication fit together very well. In fact, if the data rate is increased significantly it is absolutely necessary that wider and wider bands be used. As frequency is increased, antennas of reasonable physical size are better able to focus the transmitted beam without wasting signal in different directions. The Amateur microwave bands, through 24 GHz, offer the best available performance and cost for such communication. In order to be widely useful our link needed several attributes:

- To be inexpensive - competitive with present TNC/radio combinations
- Moderate speed - significantly faster than current alternatives of 1200/2400/9600 baud
- Medium range - at least 35 kilometers to be effective
- To use readily available parts
- To be simple to build and maintain
- To be reliable - a variety of applications may depend upon it

4. SYSTEM PERFORMANCE

The system performance depends of the gain of the antennas, free space signal propagation, cables loses and TX power. The transmitted power is limited to 10mW, which is 10dbm. The system operation margin depends of the environment parameters and is in the range of 10-15dB for safeguard work. Another parameter for the calculation of the distance between the nodes is the receiver sensitivity. Measured sensitivity of the presented demodulator is about –96 dbm. So, the link performance depends of the distance and the gain of the antenna. Figure 6 shows the gain of the antenna as function of its diameter (in centimeters); while figure 7 shows the effective range (in kilometers) of the link as function of the antenna gain in dB. Also you can see the beam width as function of dish diameter in figure 6, shown with dash-line.

The gain of the parabolic antenna can be simply calculated by the formula 1:

$$G_{dB} = 18 + 20 \, Log \, (F_{GHz} \times d_m) \quad (1),$$

where the d_m is the diameter of the antenna in meters, F_{GHZ} is the reception frequency in gigahertz.

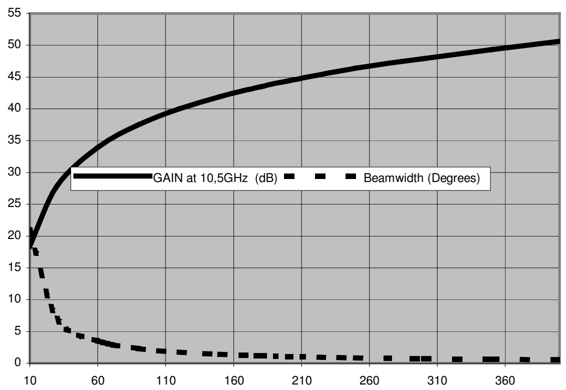

Figure 6–Antenna gain vs. dish diameter

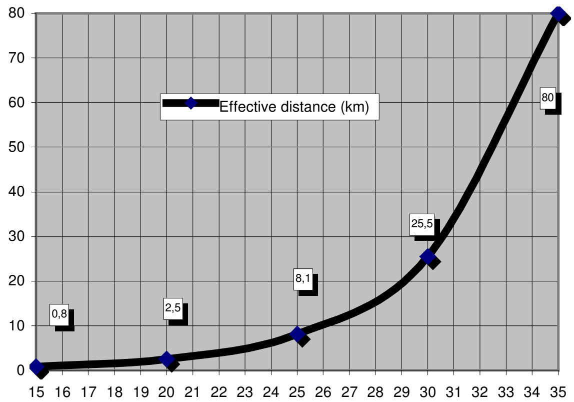

Figure 7–Effective distance vs. antenna gain

5. CONCLUSION AND FUTURE WORK

Presented radio link is simple, effective and low-cost. It is related to mid-range speed applications. Future experiment will be intended to use the presented principle for LAN wireless radio bridge at high data speed about 10Mbit/s and 100Mbit/s.

Current design is able to work up to 76.8kbit/s. The sensitivity of the receiver is very high (-96 dbm), which is very suitable for high effective long distance wireless data links.

6. REFERENCES

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