A Secure Telecommunication Link using Spread Spectrum Technique for 5G Applications

Marzie Tabatabaefar *[1], Mansoor Dashti Ardakani [1], Reza Karimian [2], and Serioja O. Tatu [1]

[1] Institut National de la Recherche Scientifique (INRS – EMT), Université du Québec, Montréal, QC., Canada.
[2] Electrical and Computer Engineering Department, The George Washington University, Washington D.C., USA.
* tabatabaefar@gmail.com

***Abstract*— In this paper, we have addressed the limitations of the six-port receiver and designed a robust, secure telecommunication system based on the spread spectrum, that can be used in different 5G applications. We have designed and simulated two different direct sequences spread spectrum links in MATLAB. These designs have made high data security, reliable communication in the presence of noise, improvement in the minimum detectable signal and transmission distance.**

I. INTRODUCTION

Several structures have been proposed for communication in the 60-GHz band. An impressive design is the six-port receivers [1], which are based on multi-port technology [2]. Six-port receivers have significant advantages such as low cost, easy fabrication, and being operational with low power in a wide frequency range. However, it has some limitations including a high free space path loss. The FCC has allocated an opening of 7 GHz spectrum in the V-band (from 57 to 64 GHz) for unlicensed short-range applications [3]. Due to more signal bandwidths in 5G, the white noise affects the signal more. Also, the Six-port receiver consists of passive components, and the noise figure in this receiver without any LNAs is high. We have addressed the limitations of the six-port receiver and proposed a robust, secure telecommunication system based on the spread spectrum that can be used in different 5G applications. The Spread Spectrum (SS) technique [4] is widely used in applications that need anti-jam protection and low probability of detection and/or interception. We have used the direct-sequence spread-spectrum (DSSS) technique [5] which is applied by multiplying the transmitted binary bipolar data sequence to a higher rate pseudo-noise (PN) binary bipolar sequence.

In this paper, two DSSS links, capable of sending two 5 Mbps and 350 Mbps of data, are designed. These designs have improved the minimum detectable signal (MDS) and transmission distance.

II. BASEBAND LINK DESIGN

Two different direct sequences spread spectrum links are designed and simulated in MATLAB to send 5 Mbps and 350 Mbps of data, with the chip factors of 2047 and 31, respectively. A general view of the transmitter part of the Simulink environment is shown in Fig. 1(a), and the available block diagram of the receiver is given in Fig. 1(b). Sending the preamble and data is controlled by the control signals. Every 31×5 clock pulses, two bits are sent to the QPSK modulation.

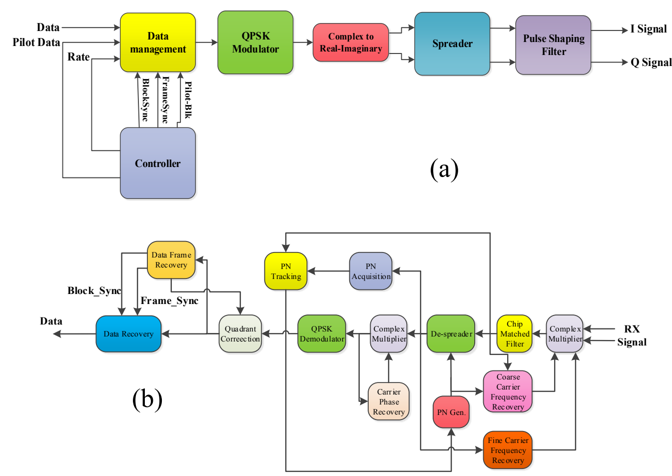

Fig. 1. The simulated blocks of (a) the transmitter part, (b) the receiver part.

Fig. 2 shows the narrowband generated signal after the modulator and before spreading. The spread signal with the PN sequence of length 31 is shown in Fig. 3. The bandwidth has expanded, and the power density of the signal has a lower level in comparison with Fig. 2. The general output signal of the transmitter in both links is shown in Fig. 4. As can be seen, the bandwidth of the signals is adjusted up to 7 GHz. The specifications of the designed links are summarized in Table I.

In the receiver, the signal is received and processed in the baseband in two orthogonal parts, signals I and Q. Generally speaking, receiver architectures are more complex than transmitters because they need to synchronize the signal. In the DSSS receiver, the very first step is to find the location of the PN code through a procedure called PN Acquisition. The PN-Acquisition unit searches sequentially to locate the PN code with a precision of one chip. Another procedure is needed to locate the PN code more precisely and track the location continuously. This system is called PN Tracking Unit. For a coherent QPSK demodulation, we have to find the phase shift of the carrier. It is done in the Frequency-Recovery Unit. QPSK demodulator unit demodulates the signal. Since the QPSK is characterized by the phase of the symbol, it is important to have knowledge about the phase and frequency of the carrier and run the phase recovery process before demodulation. The data recovery unit controls the accuracy of all other synchronization circuits.

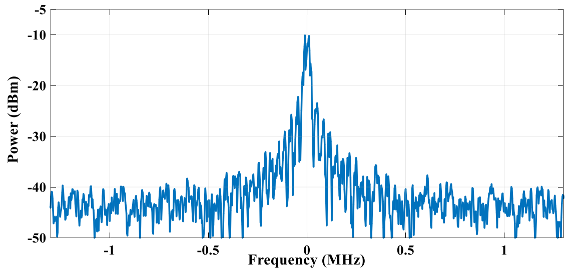

Fig. 2. The baseband generated signal before spreading.

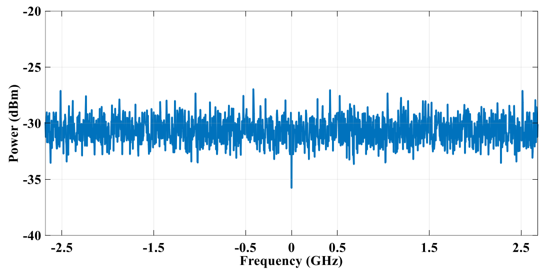

Fig. 3. The signal after spreading with the PN sequence of length 31.

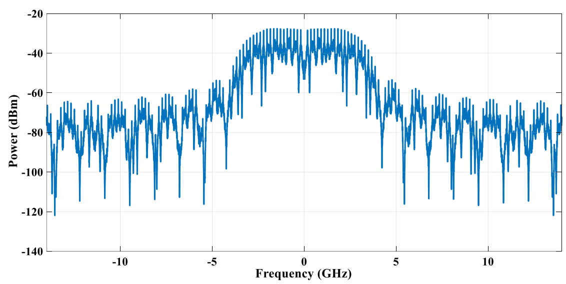

Fig. 4. The baseband signal after pulse shaping filter.

III. Results and Discussion

The minimum power level at the input of a receiver, in a way that the signal can be processed, is called the minimum detectable signal. The noise floor can be calculated as (1) in dBm to obtain the MDS in (2). The proposed designs have considerably improved the MDS at the receiver.

$$Noise\ Floor = 10\times\log_{10}(KT\times 1000) + NF + 10\times\log_{10}(BW) \quad (1)$$

$$MDS = Noise\ Floor + SNR \quad (2)$$

$$Free\ Space\ Loss = \left(\frac{4\pi df}{c}\right)^2 \quad (3)$$

where $K = 1.38\times10^{-23}$ J/K, T, BW, d, f, and c are the temperature on the Kelvin scale, bandwidth in Hertz, the distance between the TX and RX antennas, operating frequency, and speed of light, respectively.

The MDS is calculated around -44 dBm for a regular link with a transmitter and the passive six-port receiver, while the MDS in the designs with 33 dB and 15 dB processing gain is -76 dBm and -58 dBm, respectively. Note that both of these MDS values are calculated to have a bit error rate (BER) of 10^{-7} in the output of the coherent demodulation for QPSK signal. Referring these MDS values and Equation (3), it can be concluded that the designed receiver is able to detect a signal with the transmission distance almost 45 times for 33 dB Processing gain, or 6 times for 15 dB Processing gain, greater than a link without the signal processing units.

Finally, the link is implemented to send high rate data in the 60-GHz band (Fig. 5), providing data security and reliability. Without the knowledge of the existence of a spread communication and the PN sequence, the signal is almost hidden, and it is not feasible for any receiver to extract data.

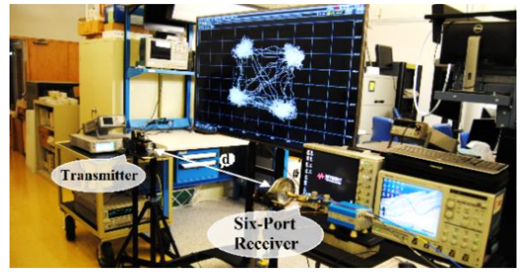

Fig. 5. The V-band wireless link experimental setup.

TABLE I. The Parameters in the Designed Link

Link Specifications	**33 dB Processing Gain**	**15 dB Processing Gain**
Number of chips	2047	31
Data Rate (Mbps)	5	350
QPSK Symbol Rate (Mbps)	2.625	183.75
Number of Samples/Symbol	5	5
Theoretical Signal BW (GHz)	6.44805	6.8355

IV. Conclusion

This paper aimed to design a link to confront the challenges in 5G by use of the six-port receiver. We have chosen the DSSS technique for its notable and striking advantages. A baseband link has been designed, with realistic channel. It is a complete high date rate link in the 60-GHz band that processes the signal in the receiver to obtain the information in the presence of noise and provide data security and reliability.

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