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Implementation and Analysis of WiMAX System to Work within Spectrum of Digital Television Broadcasting Terrestrial through the Cognitive Radio Network

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ABSTRACT: The cognitive radio networks are a modern method to meet the growing demand for wireless networks, but it has also a complex system in its structure, because they are designed to manage two systems that may be different from each other in terms of configuration, and they also contain the multiple detection Techniques, sensing algorithms and dynamics of composite work to ensure that the signals of the two systems do not interfere. Therefore, when designing such networks must make a comprehensive study and analysis of the system conducted under different operational conditions. This paper investigates how toimplementing and designed a hybrid system to work in the networks of cognitive radio and then discuss the some of signals characteristics that send through the cognitive network, so that the primary user represents the digital TV terrestrial and the WiMAX system will represent the secondary user.The study will be conducted under different working conditions so that the secondary user's mode of work will change depending on the primary user operating situation and according to the alternative solutions that the system will provide. This paper also includes the study of the effect some different types of modulation on the signal in the transmitter and receiver units through study the constellation of signal, spectral density and power analysis and finally comparing and analyzing the results. And then makes an emulation program and design the prototype device (used for educational purposes) that explains the basic principle of this system, the objectives of this device are sensing the spectrum and determine the status of the channel and then notification of the result via audio pulses. It is also used in the examination of the microcontrollers in the cognitive systems, and can be used for generatingthe signals for harmonic equipment.

KEYWORDS: Adaptive Modulation and Coding; Bit Error Rate; Cyclic Prefix; Cognitive Radio Network; Digital Video Broadcasting -Terrestrial;Primary User;Signal-to-Noise Ratio; Secondary User;Worldwide Interoperability for Microwave Access.

I. INTRODUCTION

The wireless communication systems are among the most important systems in our time, currently most of the communication systems depend on channel allocation, so that each user has a fixed frequency, and this is done through dividing the spectrum into sections according to frequencies levels. Until recently, this method was effective but with the increasing demand for wireless networks and the emergence of new applications depend on the wireless systems such as interactive systems, the Social interaction , the entry of communications in most transactions and increase the users awareness of the Internet culture .it was necessary to find the solutions and alternative means to provide services to all users with high efficiently and quality and where the frequencies are not used continuously all the time the arose idea of trading unused frequencies between users through the specific policies and controls, in which users are divided into two categories the first category represents the primary users with the highest priority to use the frequency concerned.

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The second category represents the secondary users or unlicensed users and they have the lower priority for use the frequency. "Priority" meansthat the secondary user can be exploit the frequency only in case the primary user is not activated. So that this process is done by technique called the cognitive radio (CR) .where the cognitive radio is senses the frequency and then determine the status of the channel by using one of the frequency detection technique before exploit the channel, and also ensures withdrawal from the frequency when the primary user needs this frequency. In the Matlab simulation two groups were tested model 1&2. The model 1 is represent the transmission by one burst and model 2 is represent the transmission by two burst, any model have six cases for each group make certain tests, So that each test represents a specific case as shown in the table1.

Table 1: Shows the simulation settings.

Number of case	Content of the Test (Results that can appear when testing for each case)
Case 1	Probability of the primary user utilization of frequency;Frequency is not used by any users; The frequency utilization by the secondary user; The white frequency exploitation by secondary user; Exploitation of frequency reuse by the secondary user;With the activation of cognitive property.
Case 2	Probability of the primary user utilization of frequency; The frequency utilization by the secondary user; The white frequency exploitation by secondary user; With the continuous activation of cognitive property.
Case 3	Probability of the primary user utilization of frequency; The frequency utilization by the secondary user; With the continuous activation of cognitive property.
Case 4	The frequency utilization by the secondary user all the time.
Case 5	The frequency utilization by the primary user all the time.
Case 6	Probability of the primary user utilization of frequency;Frequency is not used by any users; The frequency utilization by the secondary user; The white frequency exploitation by secondary user; Exploitation of frequency reuse by the secondary user; With the activation of cognitive property and different type of modulation for the first case.

II. ISSUES

Design and analysis of the hybrid system (Modified System) in which the WiMAX system operates within the spectrum of digital television broadcasting terrestrial through using cognitive radio technology.

III. MATERIALS AND METHODS

Designing the model of the WiMAX system by MATLAB simulation to work as secondary user in spectrum of the digital television broadcasting terrestrial through the cognitive radio network and by using the energy detection technique to detect the signal in the frequencies, and analysis of the results after that will be designing the software program and hardware device work to achieves the same purpose. The settings used in the simulation program are shown in table 2.

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Table 2: Shows the configuration of simulation.

Channel bandwidth (MHz):	7 MHz : same as TV channels (according to regulatory domain)	**Number of tests performed:**	11 cases
Number of OFDM symbols per burst:	1 , 2	**Simulation mode:**	Monte -carlo
Cyclic prefix factor (G):	1/4	**Code rate (CC):**	1/2 ,2/3,3/4
Additional Algorithms:	neural networks (NN), sorting algorithm (BA)	**Detection method:**	Energy of signal
Modulation:	QPSK,16QAM,64QAM	**Fading mode:**	frequency-selective fading
Models a multipath Rician fading channel with :	AWGN	**Rate ID without :**	1 - 6
Number of test rounds:	30 rounds	**Threshold mode:**	Single tone

IV. Modulation Schemes and Coding Rates in Matlab Simulation

The all results in this paper for the modulation schemes and coding rates have been obtained in an AWGN channel and with average of SNR is 18. As specified in the standard, allows the wide broadband internet systems that work under cognitive radio techniques is ability for use six different combinations of modulation order and coding rates for the purpose of data transmission. They are shown in table 3.

Table 3: Modulation Schemes and Coding rates.

Rate-ID	Modulation RS-CC rate
1	QPSK 1/2
2	QPSK 3/4
3	16-QAM 1/2
4	16-QAM 3/4
5	64-QAM 2/3
6	64-QAM 3/4

V. Results

A. *The results of the signal constellation for WIMAX transmitter and receiver with different modulations and modes of work:*

The increase the transmit power to the certain value Lead to improves the accuracy of the signal and the quality of signal at the receiver, but the main problem is that there are Some conditions and controls prevented from increasing energy sending a certain limit set by the IEEE because if increase the power above this limit Lead to harmful to human health and harmful to environmental and has sometimes to serious diseases,this is evidenced by studies. Also, if used the high modulation with low signal to noise ratio (SNR) will adversely effect on the quality of signal, this is shown in constellation figure 1 at the transmitters when using the same data rate.

When the signal to noise ratio is constant at 18 and the modulation is increased, the signal is begins to distortion and starts taking the random amplitude. Appears the small effect of the noise on the signal at the receiver unit that shown

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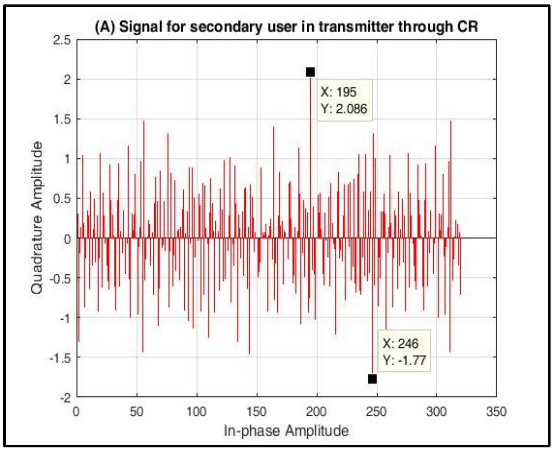
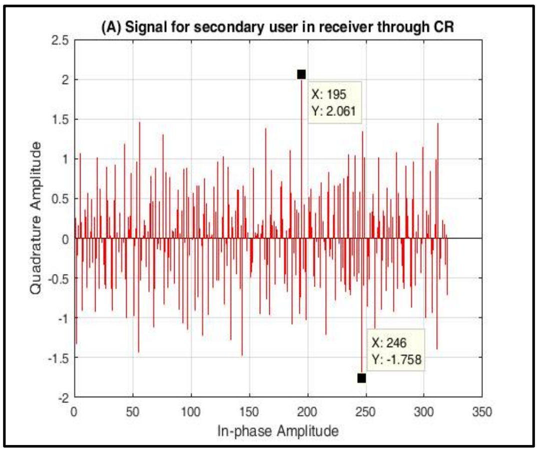
clearly in figure 1 at the receiver, and the figure 1 as general the represents the WiMAX system at work with different modes and are summarized in the table 4. Figure 2 summarizes the results of signals constellation deviation in different cases test for the WiMAX System.

Table 4: The initial settings to study the constellation of signals for WiMAX

No. of figure 1.X	Type of unit	Data rate	Rate-ID
(a)	Transmitter	L	1
(b)	Receiver	L	1
(c)	Transmitter	M	2
(d)	Receiver	M	2
(e)	Transmitter	M	4
(f)	Receiver	M	4
(g)	Transmitter	H	3
(h)	Receiver	H	3
*When L=350 bits, M=550bits, H=750bits. *X= the figure from " a " to " h"			



(a)Constellation of the signal in the transmitter unit with modulation QPSK 1/2 (WS)



(b) Constellation of the signal in the receiver unit with modulation QPSK 1/2(WS)

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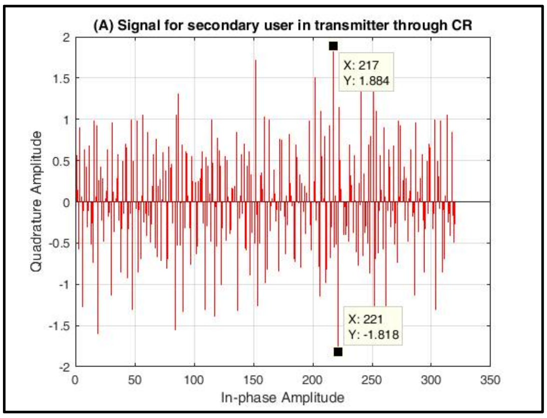
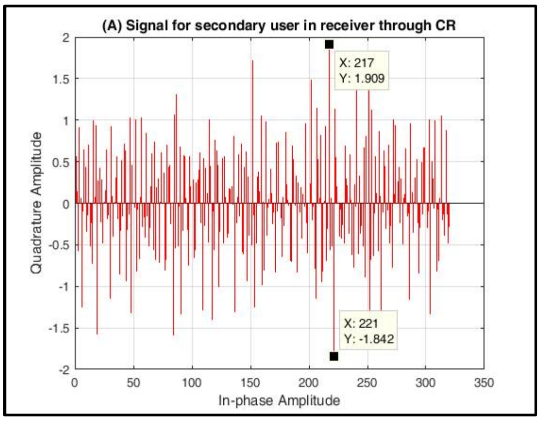
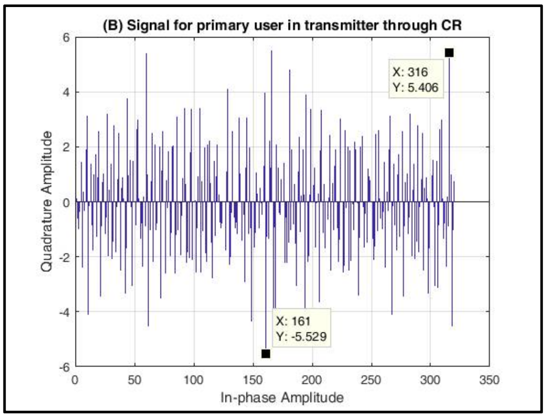


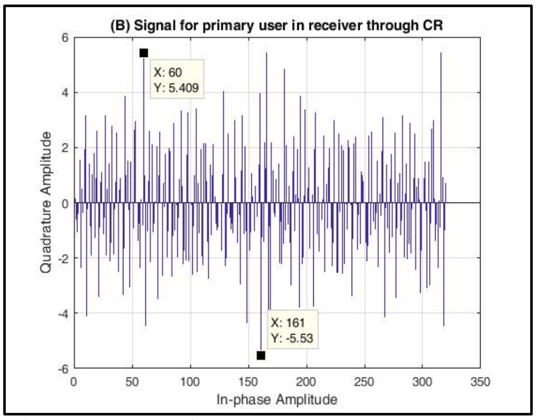
(c) Constellation of the signal in the transmitter unit with modulation QPSK 3/4 (WS)



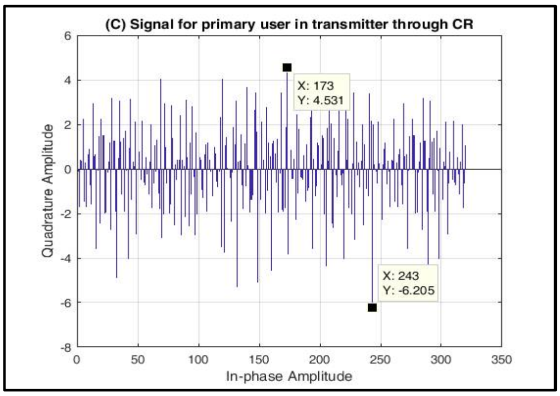
(d) Constellation of the signal in the receiver unit with modulation QPSK 3/4 (WS)



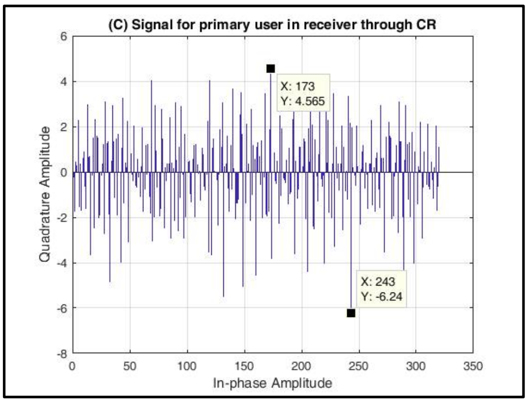
(e) Constellation of the signal in the transmitter unit with modulation 16QAM 3/4(CR)



(f) Constellation of the signal in the receiver unit with modulation 16QAM 3/4(CR)



(g) Constellation of the signal in the transmitter unit with modulation 16QAM 1/2(CR)



(h) Constellation of the signal in the receiver unit with modulation 16QAM 1/2(CR)

Figure 1: The signal constellation for the WIMAX system in transmitter and receiver with different modulations and modes of work,for small letters below the figures see table 4.

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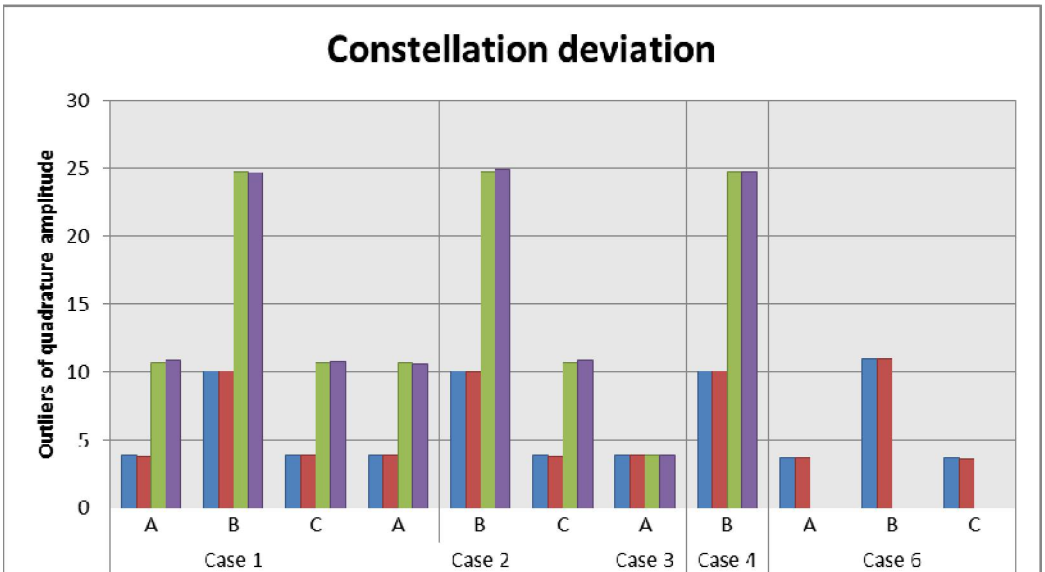

	A	B	C	A	B	C	A	B	A	B	C
		Case 1			Case 2		Case 3	Case 4		Case 6	
Tx1	3.856	10.057	3.856	3.856	10.057	3.856	3.856	10.057	3.702	10.929	3.702
Rx1	3.819	10.091	3.89	3.858	9.985	3.83	3.906	10.067	3.751	10.939	3.676
Tx2	10.736	24.79	10.736	10.736	24.79	10.736	3.856	24.79	0	0	0
Rx2	10.886	24.72	10.805	10.667	24.95	10.844	3.906	24.81	0	0	0

Figure 2: Constellation deviation of the signal in different cases for the WiMAX system.

B. *The Results of spectral density for WIMAX system in transmitter and receiver with different modulations and modes of work:*

The power spectrum a time series describes the distribution of power into frequency components composing that signal. According to Fourier analysis, any physical signal can be decomposed into a number of discrete frequencies, or a spectrum of frequencies over a continuous range. The statistical average of a certain signal or sort of signal (including noise) as analyzed in terms of its frequency content, is called its spectrum. When the energy of the signal is concentrated around a finite time interval, especially if its total energy is finite, one may compute the energy spectral density. More commonly used is the power spectral density (or simply power spectrum), which applies to signals existing over all time, or over a time period large enough (especially in relation to the duration of a measurement) that it could as well have been over an infinite time interval. The power spectral density (PSD) then refers to the spectral energy distribution that would be found per unit time, since the total energy of such a signal over all time would generally be infinite. Figure 3 explains the power spectral density for the signal used in the WiMAX system when running in the spectrum of digital television broadcasting terrestrial. Can see clearlythe distortion in the signal received in figure (b), (f) and (h) compared to the basic signal in figure (a), (e) and (g), due to adding the natural noise in this model. Table 5 shows the settings of the system to get the following results. From table 4 if the transitionto down the table the harmonica and the roll off is increased because the Rate ID also increases.

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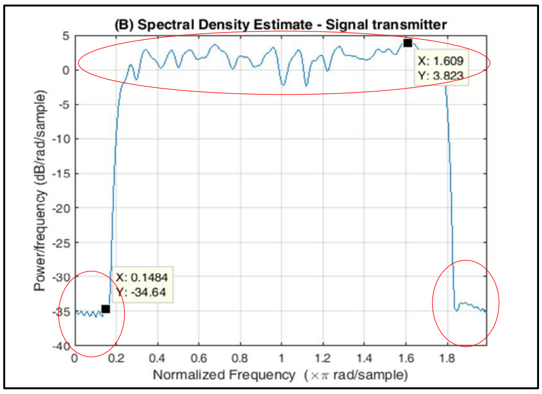
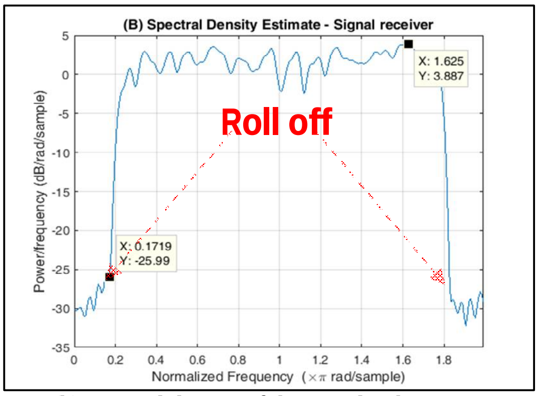
Table 5: The initial settings to study the spectral density of signal for the WiMAX system.

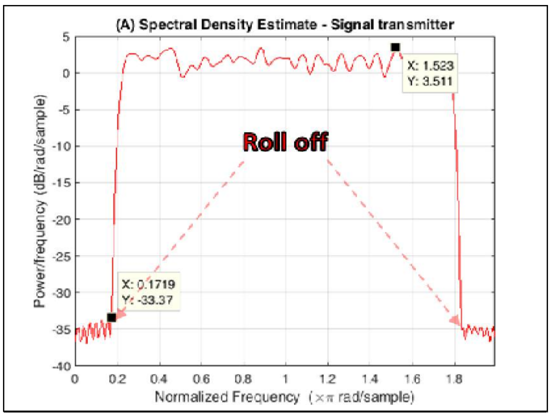
No. of figure 3.X	Type of unit	Data rate	Rate-ID
(a)	Transmitter	L	3
(b)	Receiver	L	3
(c)	Transmitter	H	3
(d)	Receiver	H	3
(e)	Transmitter	H	5
(f)	Receiver	H	5
(g)	Transmitter	H	5
(h)	Receiver	H	5
*When L=350 bits, M=550bits, H=750bits.	*X= the figure from " a " to " h "		



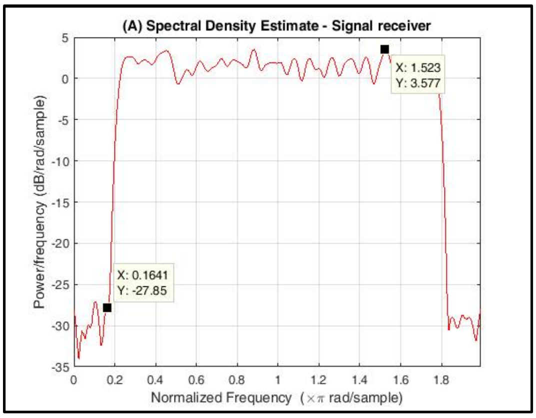
(a) Spectral density of the signal in thetransmitter unit with modulation 16QAM1/2 (CR)



(b) Spectral density of the signal inthe receiver unit with modulation 16QAM1/2 (CR)



(c) Spectral density of the signal in thetransmitter unit with modulation 16QAM1/2 (WS)



(d) Spectral density of the signal in the receiver unit with modulation 16QAM1/2(WS)

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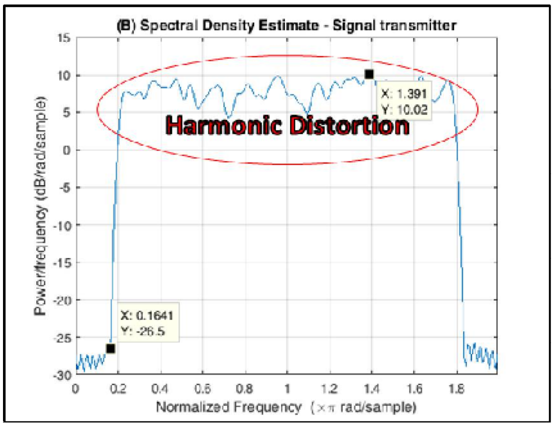
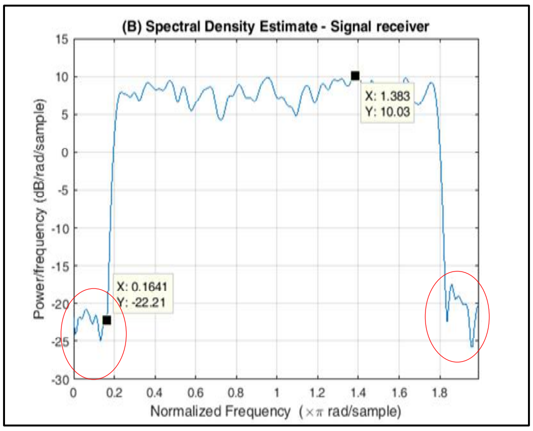
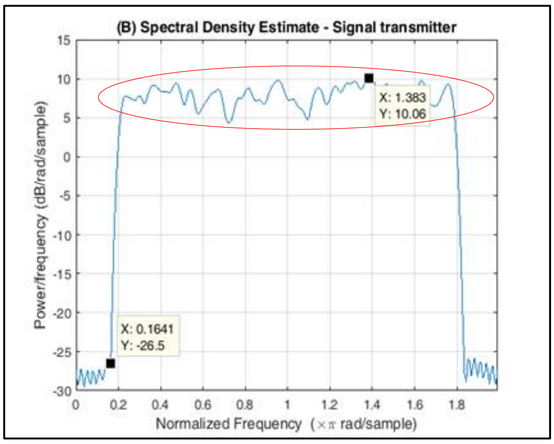


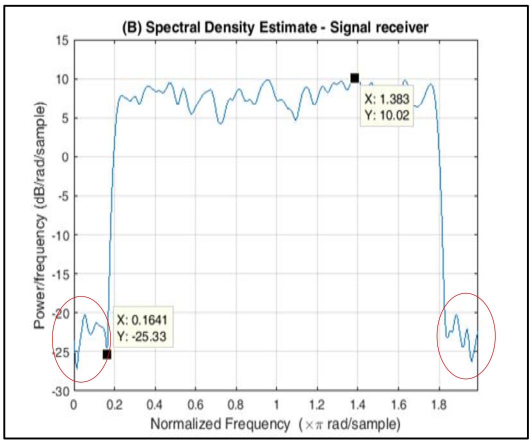
(e) Spectral density of the signal in thetransmitter unit with modulation 64QAM2/3 (CR)



(f) Spectral density of the signal in the receiver unit with modulation 64QAM2/3(CR)



(g) Spectral density of the signal in thetransmitter unit with modulation 64QAM2/3



(h) Spectral density of the signal in thereceiver unit with modulation 64QAM2/3

Figure 3: The spectral density of WIMAX signal in transmitter and receiver with different modulations and modes of work, for small letters below the figures see table 5.

C. *Theresults of power analysis of the data signal for WIMAX system in transmitter and receiver with different modulations and modes of work:*

The power by definition is the ability to find a statistically significant difference when the null hypothesis is, in fact, false, in other words, power is your ability to find a difference when a real difference exists. The power of a study is determined by three factors: the sample size, the alpha level, and the effect size. Will be discussed across several results. So the results in figure 4 shows the effect in size and distortion in the shape of power signals. The table 6 shows the settings of the system to get the following results. From the figure 4 whenever the shape of the signal is square and the depth is large that indicates the quality of the signal is good, so that it is characterized by a lack of the harmonic and roll-off. By comparing the figure (b) Vs (d) in received with the transmitted figure (a) and (c), notes that the WiMAX system achieved better performance efficiency when using the frequency within the white space for the spectrum of DTV.

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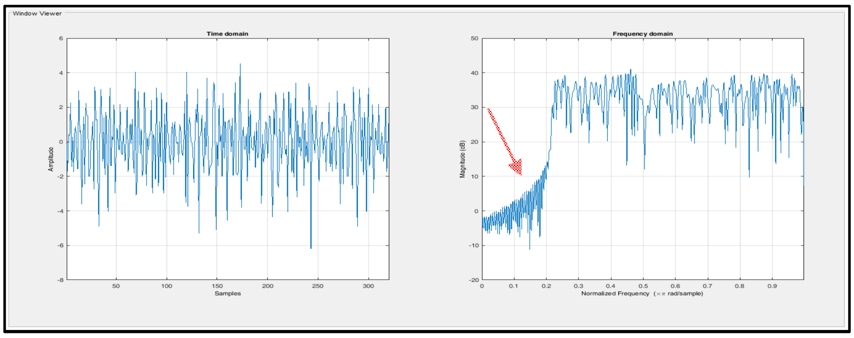
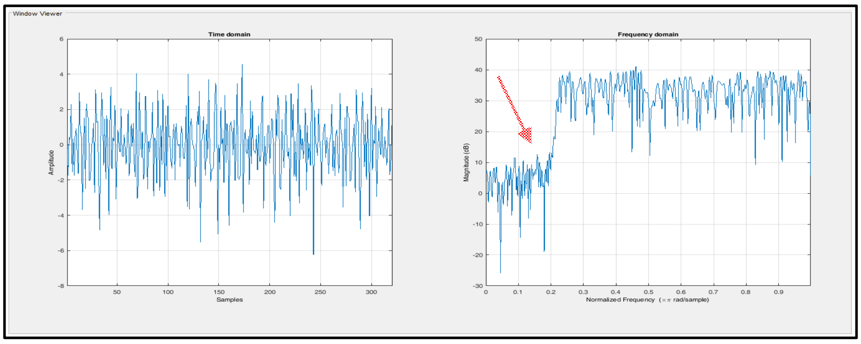
Table 6: The settings of the system to study the power analysis for WiMAX system.

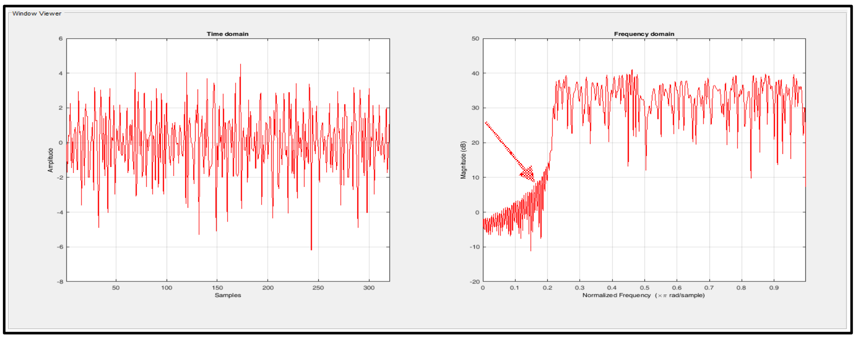
No. of figure 4.X	Type of unit	Data rate	Rate-ID
(a)	Transmitter	H	3
(b)	Receiver	H	3
(c)	Transmitter	H	3
(d)	Receiver	H	3
(e)	Receiver	L	1
(f)	Receiver	L	3
*When L=350 bits, M=550bits, H=750bits. *X= the figure from " a " to " f"			



(a) Power analysis for data signal in transmitter unit (Model 2) with modulation 16QAM1/2 (CR).



(b) Power analysis for data signal in receiver unit (Model 2) with modulation 16QAM1/2 (CR).



(c) Power analysis for data signal in transmitter unit (Model 2) with modulation 16QAM 1/2(WS).

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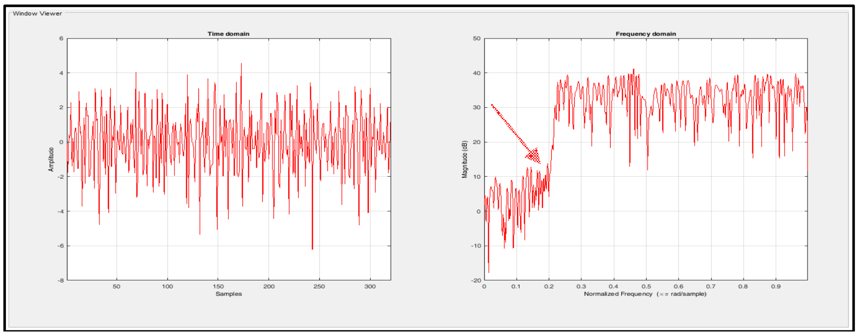
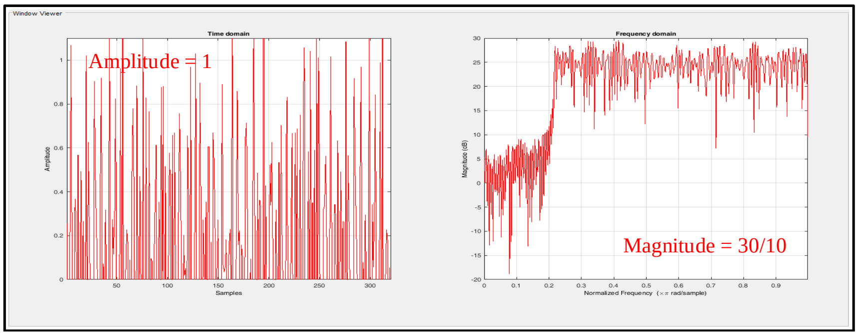
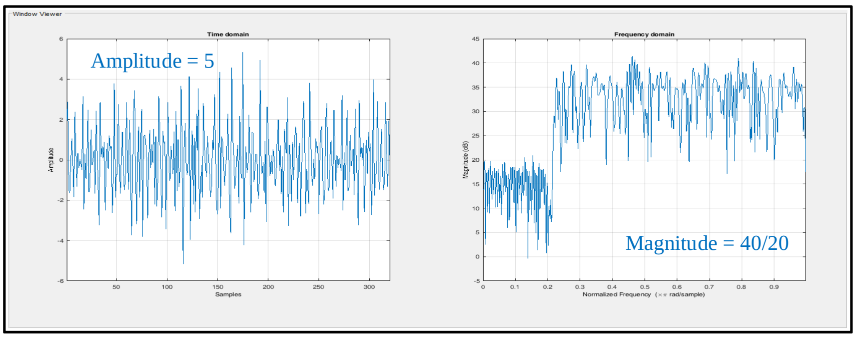


(d) Power analysis for data signal in receiver unit (Model 2) with modulation 16QAM 1/2 (WS).



(e) Power analysis for the data signal in receiver unit (Model1) with modulation QPSK 1/2 (WS)



(f) Power analysis for data signal in receiver unit (Model1) with modulation 16QAM1/2 (CR).

Figure 4: The power analysis of the signal in transmitter and receiver with different modulations and modes of work,for small letters below the figures see table 6.

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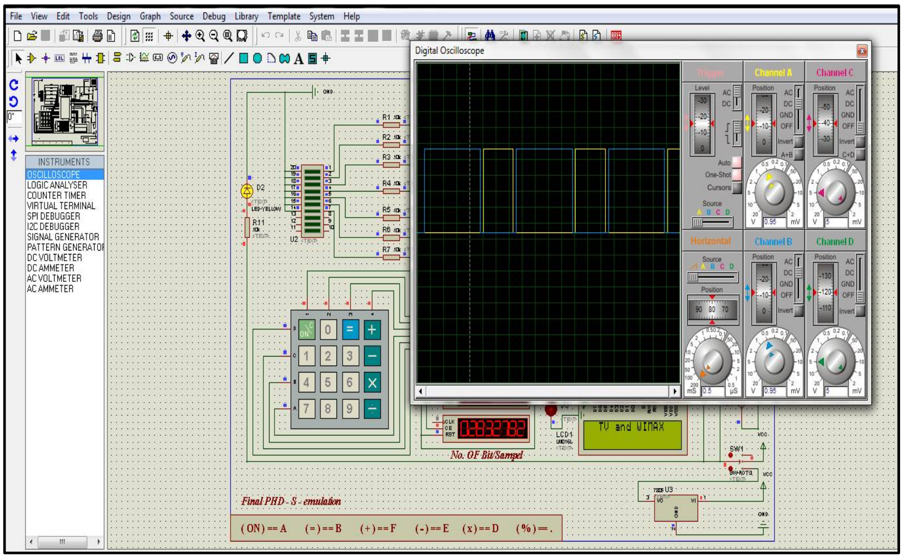
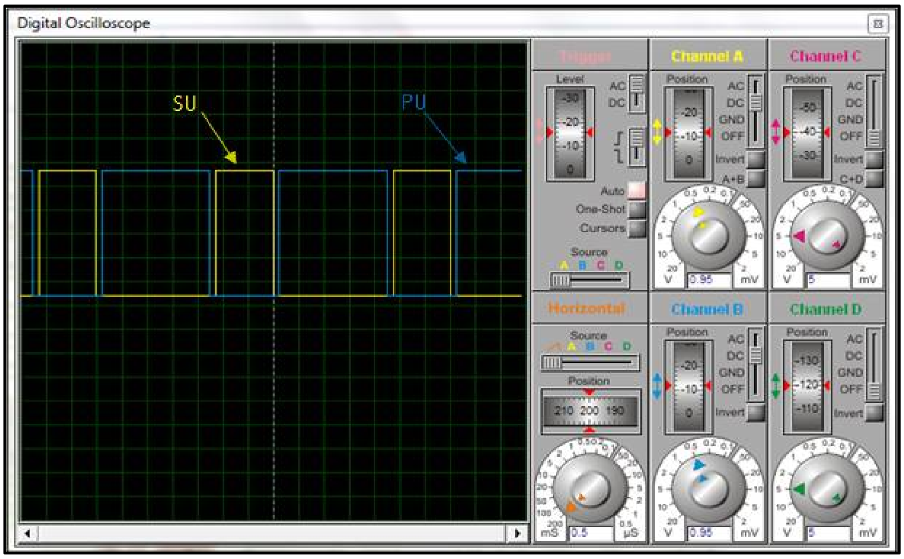
D. *The Results of Prototypes for the Smart Calculator-v2:*

The practical results have been implemented through two types the emulation method and practical models industry. The figure 5 shows representation of the emulation of the Smart Calculator model through the proteus ISIS 7 professional program, the figure 5 (a), (b) shows the smart calculator model, and can be observed the relay mechanism and how to allow secondary user working during periods when the primary user is not activated.



(a) The first practical model (Smart Calculator-v2) and its outputs by implementation through an ISIS program.



(b) The digital oscilloscope shows the secondary user works within the white spaces of the primary user spectrum.

Figure 5: (a) and (b)Shows the secondary user (WiMAX system) works within the white spaces of the primary user (TV).

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E. *The Model for Smart Calculator - V2 in different stages:*

This device in version one was designed to be used by the engineers or persons authorized to deal with the communication systems subsidiary of telecommunications companies the service provider for the purpose of setting and adjusted the networks. Currently, in the new version has been added new properties in this device are the possibility of sensing the radio spectrum and the possibility of used in the examination of the microcontrollers for some miniature amateur models which serve the same purpose. The figure 6 shows the parts and components of the smart calculator v2.

1 - Device in the form of emulation:

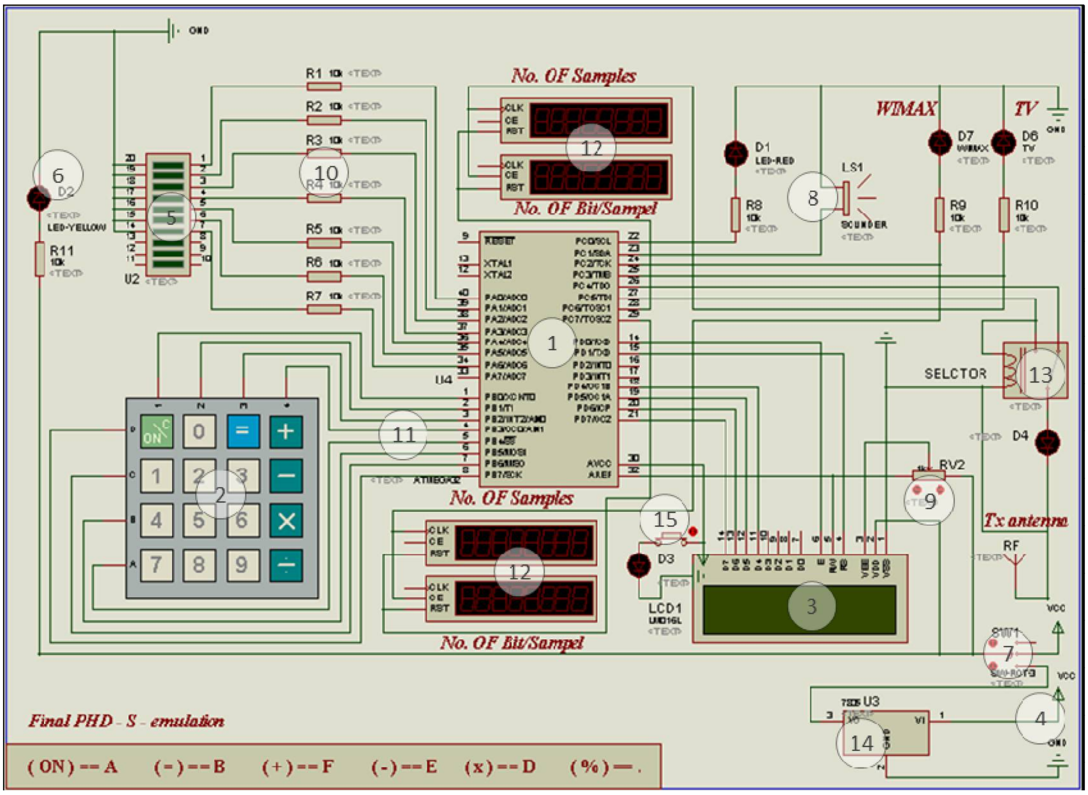

Figure 6: The practical part for S.C.v2 represented by an emulation program.

The figure 6 shows the parts of the model which the Microcontroller ATMEGA32 appears in no. (1) To works as a unit of processing, controller, comparison and making decisions also contains a program with high efficiency has been programmed by BASCOM language. Keyboard 3 * 4 appears in no. (2) in the drawing is working as input unit for data entry and directives. Screen Display LCD 2 * 16 is working as a unit of output and directing, LCD appears in no. (3) in the drawing, its mission is connecting with Processor and show the internal processes that are done within the processor. Battery rechargeable 5 volt DC appears in no. (4) in the drawing is working as a source of energy. Light Emitting Diode appears in no. (5, 6) in the drawing is working as sign of the values determined by the output. The On/Off switch appears in no. (7) in the drawing is working to control the operation of the device. Siren appears in no.(8) in the drawing working to alarm and Sound notifications.

Capacitors and Resistors fixed and variable appears in no.(9, 10) in the drawing works to adjust the screen and save the components. Data Cable appears in no.(11) in the drawing for the transfer of data and directives between parts of the system. LED Screen appears in no. (12) Used to show the results of the internal counters of the controller. Relay appears in no. (13) This is the specialized part to change the handling of terminal equipments. Transfer Switch appears in no. (14) It is the part responsible for switching between the feed sources of the device. Push Button switch appears in no. (15) to control the backlight of the display.

2- Device in the form of Prototype:

The prototype of smart calculator-v2 was used the several programs they are as follows used the BASCOM-AVR to write a microcontroller program, used the ISP programmer to programming the microcontroller (Burn the program), used the Khazama programmer to program interface to burn the program into the microcontroller .and then designed after making sure of the mechanism of work, the figure 7 shows the ISP programmer and figure 8 shows the Smart Calculator during manufacturing, can be extracted the mechanism from the flowchart in section number F&G.

Figure 7: The ISP programmer.

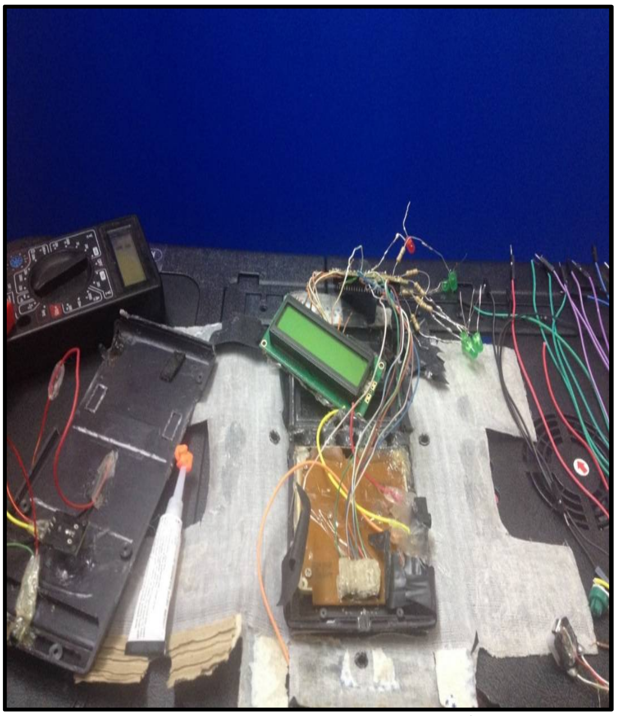

Figure 8: Smart calculator during manufacturing.

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3- Device in the form of Producer:

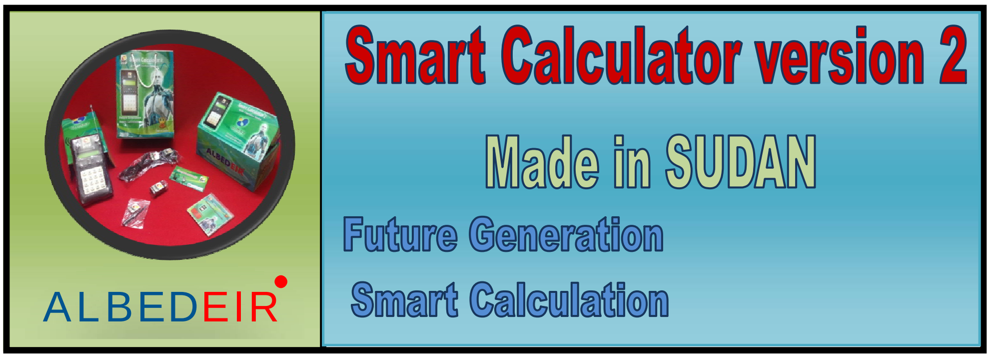

Figure 9: Shows the device in the form of producer.

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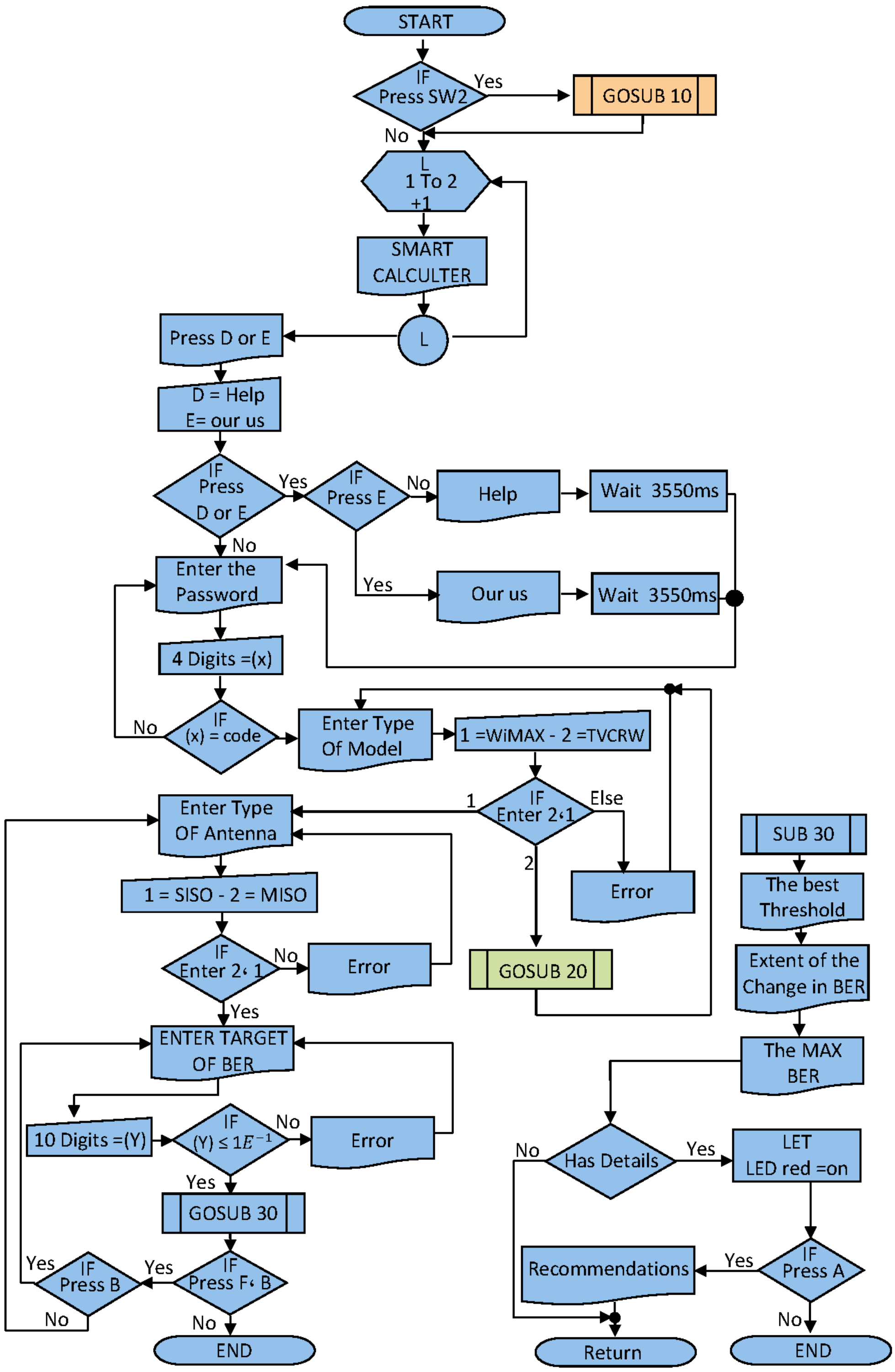
F. *Flowchart for smart calculator v2 model shows the mechanism of work the device:*



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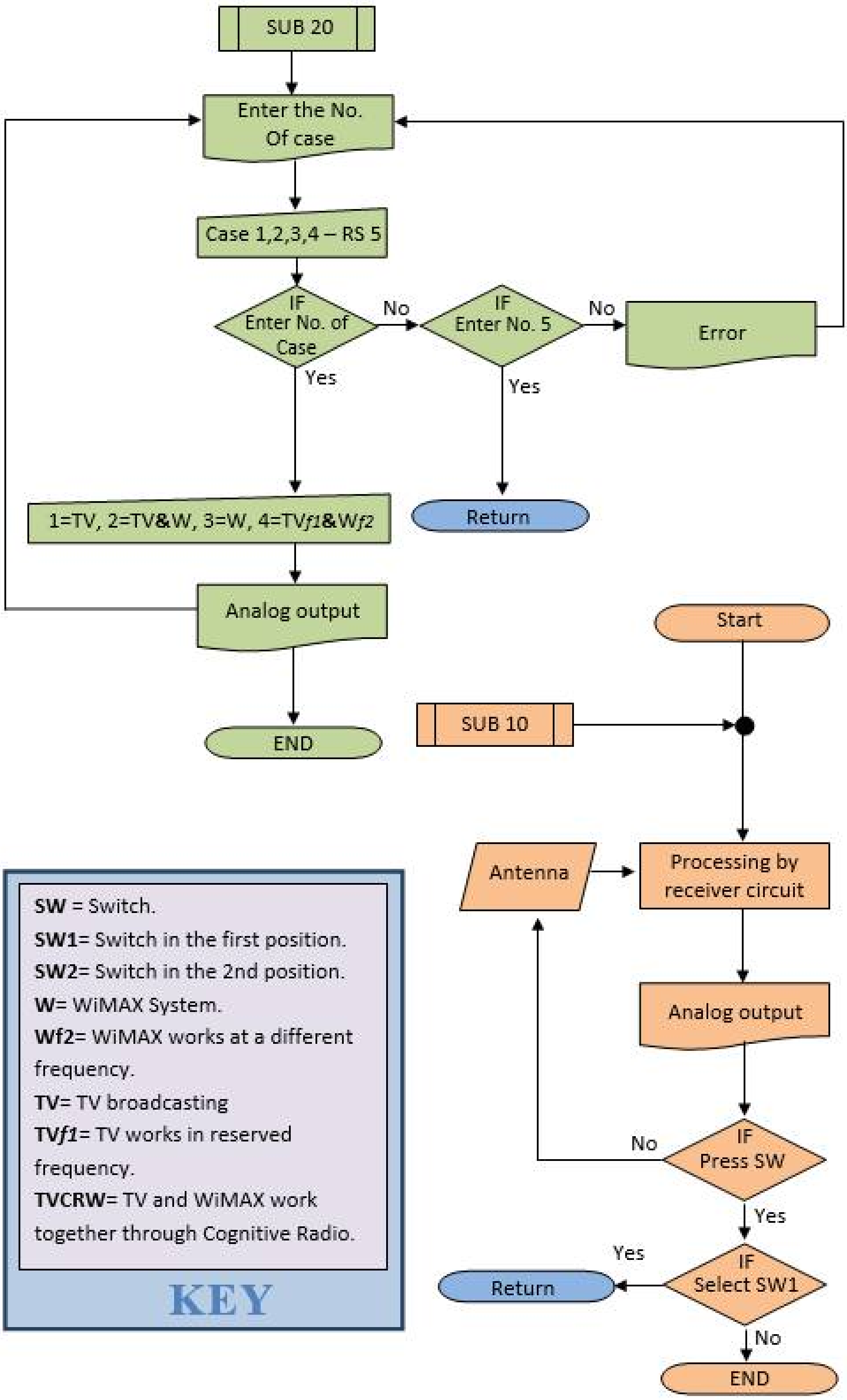

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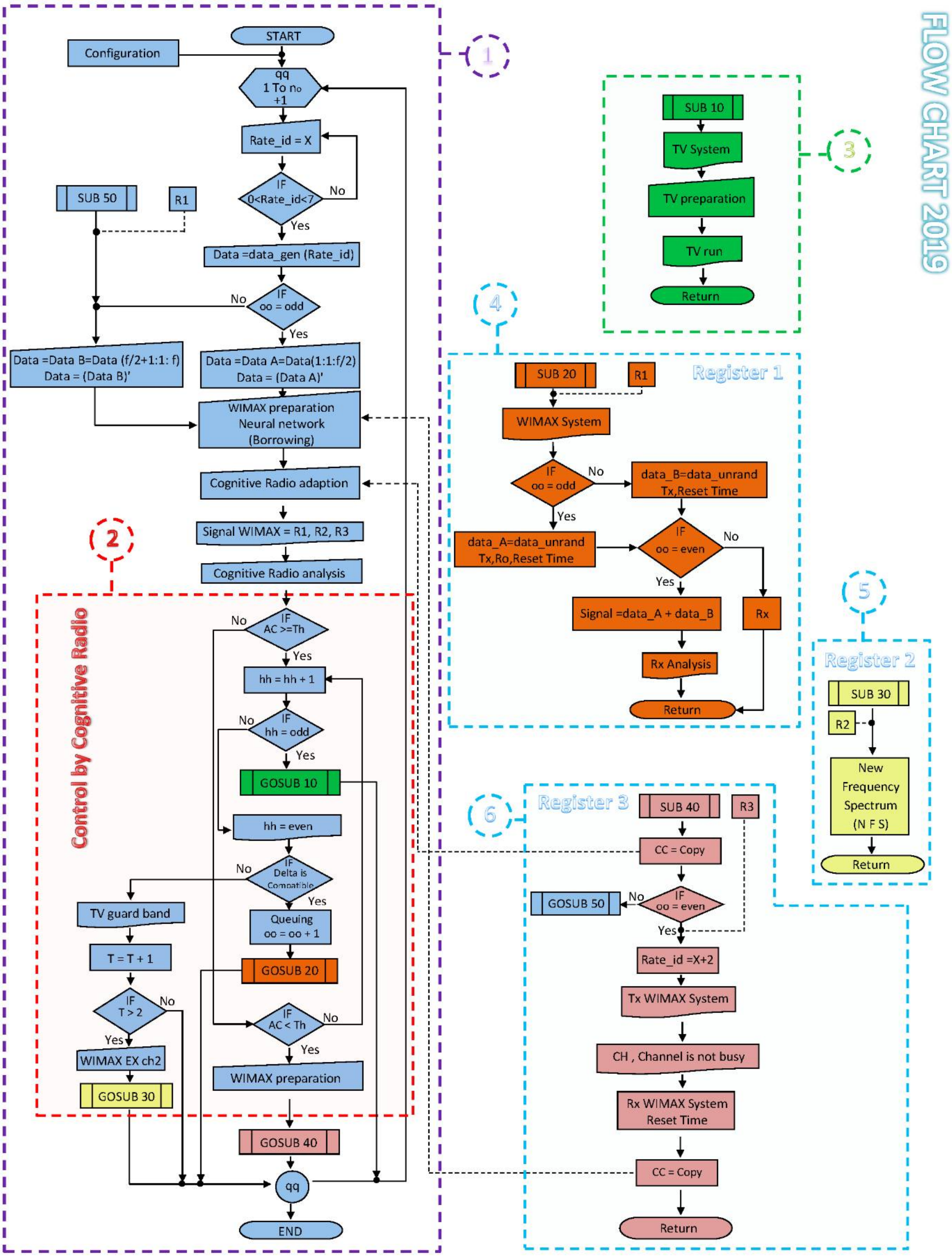

Configuration: in start: oo=0, hh=0, pp=0, qq=0, G=1/4, no=T*2 , T=15, s_f=0, q_f=0, m=5, N =2*m, Base= 0.01:0.5:1, Pf =Base.^2, snr_avgdB =5, snr_avg= power(10,snr_avgdB/10, Tu=224e-6, T=Tu/2048, GG=1/4, delta=G*Tu , Ts=delta+Tu.rate_1=QPSK. rate_2=16QAM, (QPSK-16QAM,CR=3/4)

G. *Flowchart for the simulation model shows the mechanism of work the integrated system:*

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VI. CONCLUSION

In this paper, thesimulation resultsconsideredthe effect of the modification on the properties of the signal and implications of using the high modulation with low signal to noise ratio and then design a device works to adjust the AMC. In addition to its work as a sensor for the radio spectrum and also used for educational purposes. Also canextraction the following conclusions in light of this study, the modulation curves via OFDM are less than the general representation curves of the modulation schemes. Increasing the modulation degree without taking into account determinants and controls negatively affects the signal, this result can be seen in figure 1(d), (f) andfigure 2.The power signal is affected if used the high modulation degree with lower data transmission rate, see figure 4 (e), (f).

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