Amirkabir University of Technology
(Tehran Polytechnic)
Vol. 45, No. 2, Fall 2013, pp. 29- 42

Amirkabir International Journal of Science& Research
(Electrical & Electronics Engineering)
(AIJ-EEE)

Rain Attenuation Prediction at Ku Band Using Satellite Signal Beacon Measurement in Iran

R. Bahri[1*], S. H. Maddah Hosseini[1], L. Mohammadi[1] and H. Yarmohammadi[2]

1- Faculty Member, Iran Telecommunication Research Center (ITRC), Tehran, Iran
2- PhD. Student, Tehran University, Tehran, Iran

ABSTRACT

In this paper satellite wave propagation at Ku and Ka band is considered. The design and simulation of a typical satellite beacon receiver at Ka band is designed and simulated for the future works. Also rain attenuation prediction at Ku band using satellite signal beacon measurement and simulations for Iran Telecommunication Research Center (ITRC) are presented. The measurement setup consists of two simultaneous measurement stations: satellite signal beacon measurement station and automatic weather measurement station. Within the period of January to June 2012, beacon signal level and rain rate were simultaneously recorded, collected and analyzed. The results of these measurement are compared with ITU-R attenuation model. The comparison shows that there are some differences between ITU-R and measured data. The main conclusion of this paper is that using global rain attenuation prediction models is not suitable solution in local satellite link design and detailed satellite wave propagation study at local points are necessary. Finally design and implementation of the propagation software is described.

KEYWORDS

Rain attenuation, Beacon signal, Ku and Ka band, Satellite communication, Satellite wave propagation.

* Corresponding Author, Email: reza.bahri@itrc.ac.ir

1- INTRODUCTION

The rapid growth of satellite communication systems and services has led the space industry to be considered more seriously in recent decades. Using higher frequencies such as Ku and Ka band have highlighted a need for estimating the effect of different propagation impairments. However, the specific capacity of satellite communication to respond numerous requests and services for communications have increased satellite communications importance.

Nowadays, using Ku (14/12 GHz) and Ka (30/20 GHz) bands for satellite communications have many advantages such as wider bandwidth, higher data rates, more data capacity, smaller size of component and subsystem and small size of ground stations.

Through the propagation path between the satellite and ground station, some natural phenomena such as atmospheric gases, water vapor, oxygen molecules, clouds, rain, dust and fog, existing in different layers of the atmosphere including troposphere and ionosphere, can cause some major impairment on the availability and quality of satellite links during service period. This natural phenomenon caused errors and problems such as attenuation, changes in polarization, fading, delay and dispersion. Particularly at higher frequencies such as Ku and Ka bands the effects of those propagation phenomena will not be negligible and should be considered seriously.

The effects of containing water particles are considerable. Rainfall is one of the most affecting atmospheric phenomena in the satellite wave propagation. Signal absorption and scattering are two important effects of raindrops for frequencies above 10 GHz, because it can cause largest attenuation and is usually the limiting factor at Ku and Ka band satellite link design [1].

For reliable and secure satellite communication, theoretical and experimental propagation studies in different frequencies and regions are essential. During satellite service period, impairments of propagation such as signal absorption and scattering should be considered and therefore to improve link availability, it is essential to prepare a suitable link margins and some techniques, such as site diversity.

Several theoretical and experimental studies of rain attenuation can be found in many literatures. Some of these papers are summarized in Table 1. However in our country, Iran, these measurements are the first reported results. It should be considered that measured rain attenuation data is still insufficient in order to estimate the link within the individual satellite signal beacon.

There are different methods to study satellite wave propagation such as radar, radiometer and signal beacon method. Satellite signal beacon method is one of the most important, reliable and inexpensive method in comparison with the other methods. Satellite beacon is a reference signal with a fixed frequency and power and without modulation that is sent usually by satellites. This signal has its own specific transponder with telemetry satellite signal. In some cases, the signal is buried between the data transponders. Satellite beacon is usually created by a fixed crystal source that has low intermodulation and phase noise. This means that most energy exists in a narrow bandwidth in a center frequency [1]. Beacon signals can be as much as 40-50 dB below the composite carriers. Satellite beacon receiver has to locate the beacon signals and measure its power level. Since all of the signal energy is close to the carrier frequency, satellite beacon receiver has a narrow bandwidth on the earth. Therefore, the noise in the receiver that is proportional to the bandwidth is very low. In this receiver, bandwidth of IF section should be low because the received signal power is very small which is achieved by high dynamic range [2].

TABLE 1. SUMMARY OF SOME THEORETICAL AND EXPERIMENTAL STUDIES ON RAIN ATTENUATION

Ref	Summary
[2]	A climatic map of rainfall attenuation for Turkey is developed. For this purpose, meteorological data with a 24 hour integration time for 214 sites throughout Turkey is gathered and processed to obtain a 1-5 minute database. In the second stage, the attenuation is predicted by the Leitao-Watson (1986) model. In the final stage the regional and global attenuation maps are prepared by a contouring procedure, depending on exceedance probabilities, frequency, polarization and satellite position. Rainfall intensity and attenuation maps for all possible Earth-space links at frequencies between 10-30 GHz are produced, and the predicted results are compared with the measured values to evaluate the accuracy of the model
[3]	The statistical analysis were carried out on the measured rainfall attenuation data were described. This paper presents result of measurements of rain attenuation for signals propagating at 12.2525 GHz during some rain periods. The measured attenuation was compared with that obtained using three different models
[4]	Analysis of experimental data compared against existing rain attenuation prediction models which have been used previously in satellite communication systems is presented. Data analysis was conducted in two ways. At the first, by performing statistical analysis on rain attenuation prediction models; and secondly, by making a comparison between measured data and the rain attenuation prediction model.
[5]	Modifications to the International Telecommunication Union (ITU-R P.618-10) model and an appropriate rain attenuation prediction model for tropical countries is reported. The model was developed based on data obtained from tropical and equatorial regions.

In recent years, different designs of satellite beacon receiver (analog and digital) are proposed and implemented [7]-[11]. Beacon signals are used for various applications including precise orientation of the earth station to the satellite, automatic frequency control and satellite propagation research. These cases demonstrate the importance of using the reference beacon signal. To receive satellite beacon, an appropriate receiver is needed. Locking on satellite beacon signal is hard. Though conventional satellite receivers are also generally able to track the beacon signal, the nature of the signal is led to create a special receiver.

In this paper, the design and simulation of a satellite signal beacon receiver have been done in Ka band. Also the relation between rain attenuation and rain intensity on radio wave propagation along downlink in Ku-band is shown through experimental measurement. The comparison of the estimated International ITU-R model and measured data is presented. It should be considered that this measurement at Ku band is the first experimental study on link propagation study at ku band in Iran by Radio Communication Group of ITRC. Finally, according to the reported technics and standards design and implementation of the satellite wave propagation software is presented.

It should be considered that presented results in this paper is the conclusion of the "satellite wave propagation feasibility study" in Iran Telecommunication Research Center (ITRC), has been done during 2012 [16-21].

2- SATELLITE BEACON RECEIVER DESIGN AND SIMULATION

2-1 SATELLITE BEACON RECEIVER DESIGN

The proposed satellite propagation experimentation setup is presented in Fig. 1. As shown in Fig. 1, simultaneous measurement of satellite beacon signal and weather parameters should be done. In this paper design of a typical Ka band satellite beacon receiver for propagation experimentation is presented.

Considering attenuation of propagation is over 200dB in satellite signal path of fixed geostationary satellite orbit to the earth, the received power level at the input of the antenna is smaller than -100 dBm. According to the parameters of this system; the receiver must have high gain, low noise factor, desirable frequency stability and appropriate phase noise. The designed receiver with a LNB as an input and a super heterodyne receiver are presented in Fig. 2.

In Fig. 2, the LNB output is connected to the biasing block. IF and DC parts are separated and LNB supply is fed by a separator that includes bypass capacitors and RFC inductors.

The output of the biasing block is the IF signal that can be amplified by the IF amplifier and the intended band will be selected by the filter. Since the IF frequency is still considerable amount at this stage, therefore, an additional step is required to reduce frequency by a mixer and local oscillator in the 2 GHz range.

The advantage of this circuit is that amplifying and channel selection processes take place in several stages. This simplicity of implementation especially about the filters of the channel selection, will remove the oscillation problem of the large gain in the RF and the contrast between sensitivity and image frequency. The employed LNB has standard waveguide input in the desired band, therefore in the antenna output after antenna feed we can use waveguide filter.

The LNB is fed by IF output. The appropriate gain, ultra-low noise factor and good internal consistency of the local frequency are its features. In Fig. 3, the received signal at the input antenna after entering into the LNB is given by a narrow band filter. Bandwidth of the filter forces a restriction on the size that can be implemented and manufactured. This filter should have as much as possible low attenuation in the pass band. Given that low bandwidth filters have more loss, it can be said that the system noise figure must be also considered in the design of filter bandwidth.

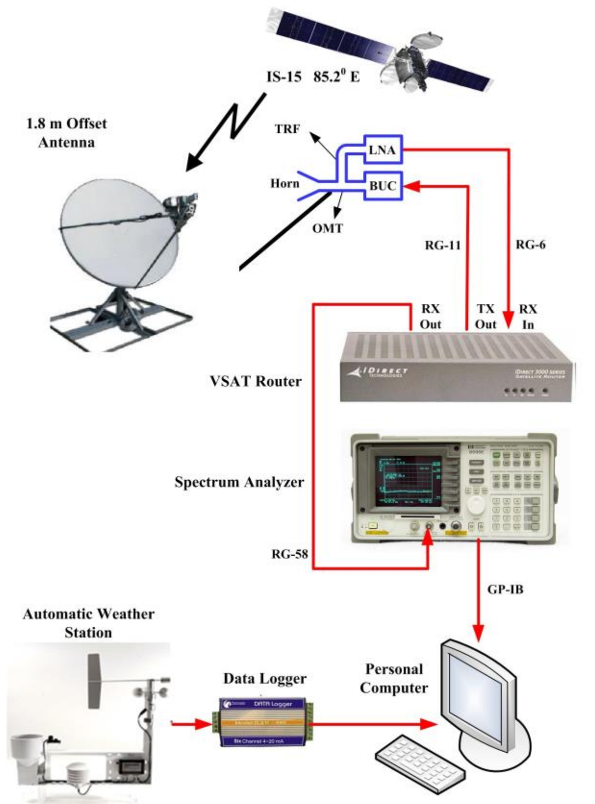

Fig. 1. Block diagram of the experimental system at ITRC

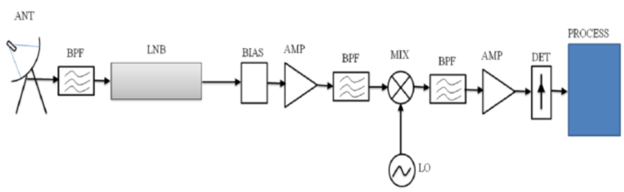

Fig. 2. Block diagram of the designed receiver

To compensate mixer conversion losses, attenuation of filters and increasing the signal power level, one or more IF amplifiers after IF filter can be used. After suitable amplification, the output signal is applied to the detector that follows the square law. Therefore, the output voltage of the detector is proportional to the input power level. The detector voltage is sampled by analog/digital converter and required conversions in the digital part are implement on it.

In this block, because of ultra-low bandwidth and relatively high frequency of the beacon signal, stability of the used local oscillator is important. To build local oscillator signal (LO) a very high stable and low frequency oscillator such as TCXO as frequency reference in the phase loop system, can be used and frequency is increased. If direct implementation of the LO signal was not possible by PLL, to achieve the desired frequency should be used of active or passive frequency multiplier such as SRD diode and desired LO frequency is separated of unwanted products by a band pass filter [12].

2-2- SIMULATION RESULTS OF THE SATELLITE BEACON RECEIVER

The proposed block diagram is simulated for receiver. In this simulation most of the element models are derived from Datasheet parts. Simulation of the supposed signal beacon is done in the Ka band at the frequency of 21.215 GHz and the power about -110 dBm in the output of the receiver antenna. It should be noted, the selected components are chosen in such a way that is usable in frequency ranges of the LNB output in the Ka band.

Designed synthesizer has adjustable frequency which can be used in other than the frequency used in this article. Due to the input beacon frequency and LO frequency related to LNB, IF1 frequency is equal to 965 MHz. IF2 frequency is designed equal to 90MHz by designing LO2 equal to 965 MHz. Thus filters and other components are used proportional to the circuit position in these frequencies. Simplified LNB model in the simulation are presented according to LNB specifications of 9000HD model which is built in Norsat Company [14].

Simulation of used unknown parameters such as the gain distribution, local oscillator parameters, and characteristics of the filters is performed in accordance with conventional systems. Results of LNB simulation for different power levels of the input frequency 21.215 GHz are presented in Fig. 3. The output of the module is saturated when the input is greater than -50 dBm.

To design the desired PLL, some specific software is applied. Used synthesizer is ADF4350 which is a product of Analog Devices Company [15]. The required parameters such as the desired output frequency are adjusted to suit the demands. The design is done for output frequency 875 MHz. Loop bandwidth and other parameters are selected to suit the needs of projects. In Figs. 4 and 5, the time response and phase noise of the PLL is represented respectively. As seen, the PLL is locked after a very short time and has a low phase noise. AD8309 model which is a product of Analogue Device Company is used as log Amp detector [15]. This element has been modeled by nonlinear relationships and blocks. In Fig. 6, the response of simulation is presented which shows that above -70 dBm, the logarithmic functionality is achieved. Output slope is 20 mV/dB and TSS value is about -80 dBm.

Also IF1’s filter is simulated. Because of the required narrow bandwidth, the designed filter must have low losses and high *Q*. For this reason mechanical inter digital filters are chosen as the best option. Due to the high gain of LNB, loss of this filter has little effect on the overall system noise figure.

Frequency characteristic of the designed filter is given in Fig. 7. As S_{21} curve shows, the insertion loss is negligible in the pass band. Integrated crystal filters have been used for IF2. These filters are typically used at frequencies below 100 MHz and features include a bandwidth that is ultra slim and low loss. According to the desired specifications of the filter, a response of the simulated model for this filter is as Fig. 8. In Figs. 9-12 harmonic responses of the system are presented at the output of each module. Level of the power of the primary carrier and largest spur are specified by markers m1 and m2.

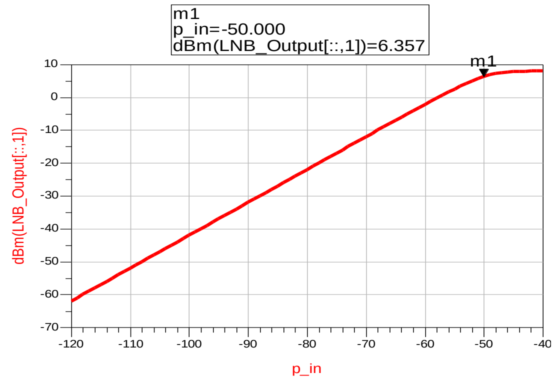

Fig. 3. Input-output characteristic of the LNB

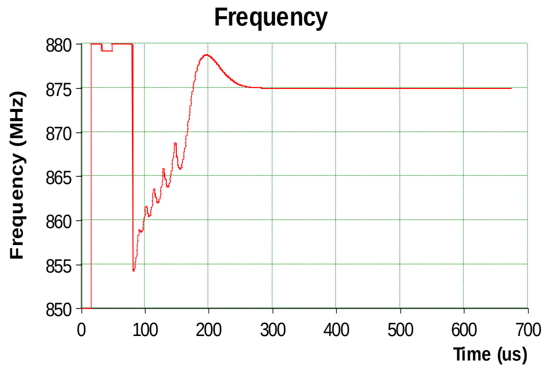

Fig. 4. Time response of the PLL

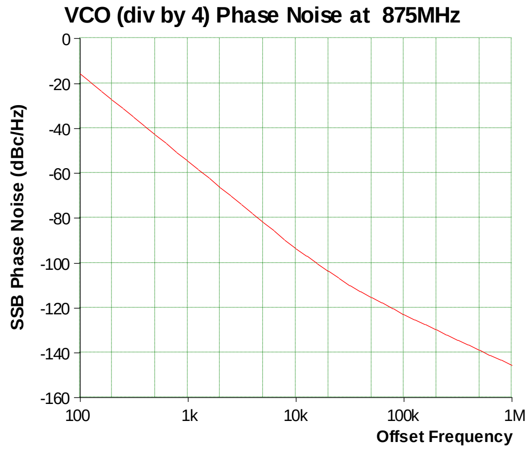

Fig. 5. Phase noise of the PLL

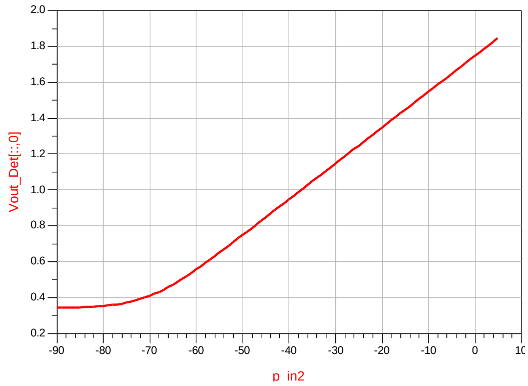

Fig. 6. Characteristic curve of Log Amp

The curve in Fig. 13 presents the output voltage of the detector. Considering the saturation characteristics of the receiver, around -68 dBm input power saturate designed receiver. Also according to the characteristics of the system, dynamic range is about 90 dB. In Fig. 14, some features of the system such as NF, SNR, TOI, IM3, and P1dB are plotted relative to the output of each module. End points of each curve represent the final value of the parameter for the entire system. For example, the system gain is 95.27 dB and the noise figure of the system is 1.676 dB.

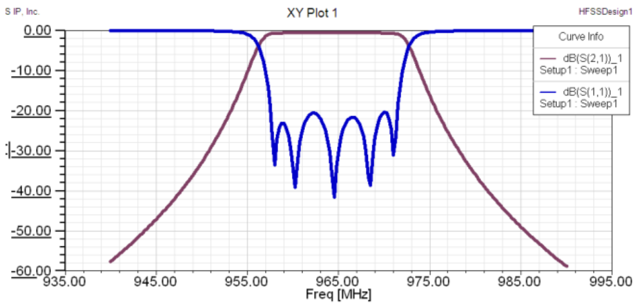

Fig. 7. Frequency specification of IF1 filter

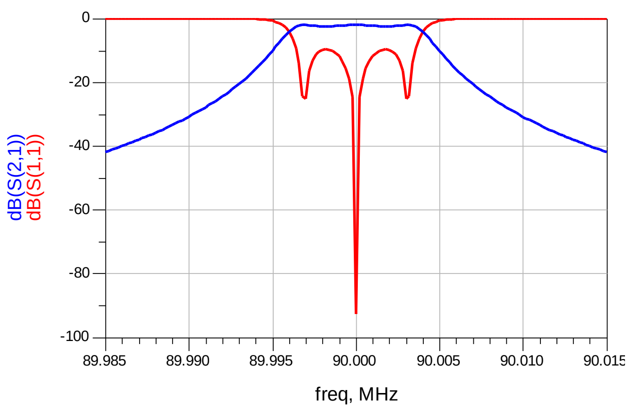

Fig. 8. Frequency specification of IF2 filter

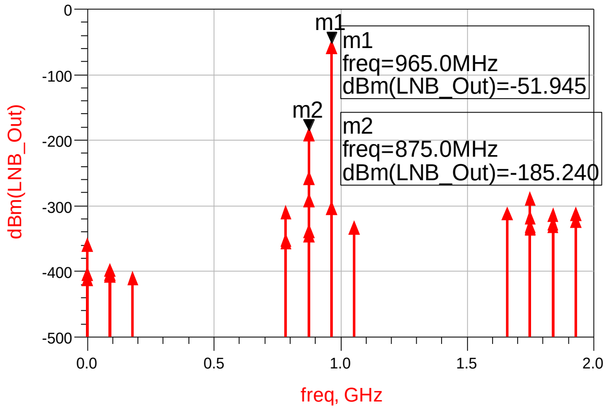

Fig. 9. Harmonic response at the LNB output

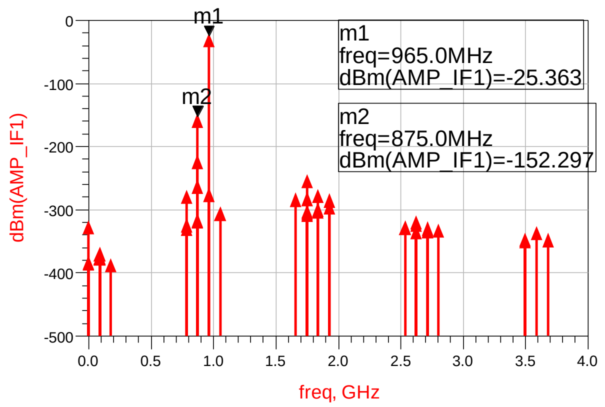

Fig. 10. Harmonic response at the IF1 output

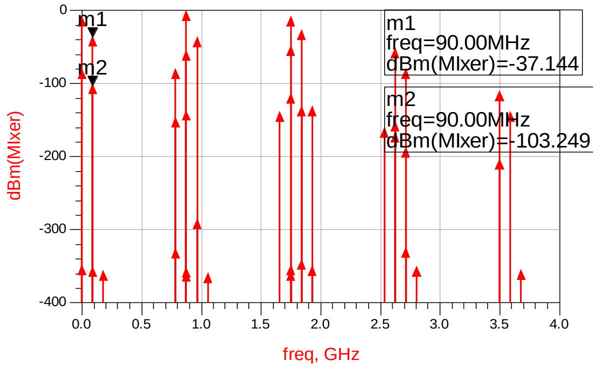

Fig. 11. Harmonic response at the Mixer output

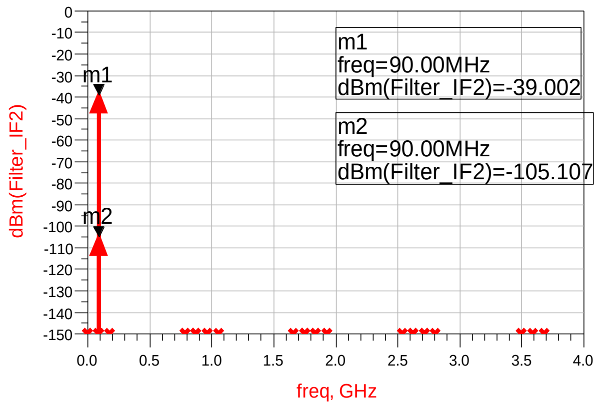

Fig. 12. Harmonic response at the IF2 output

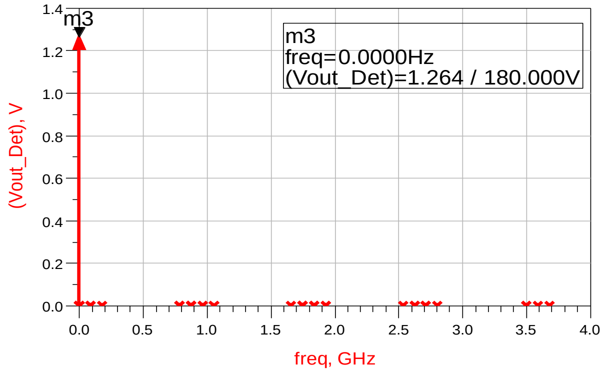

Fig. 13. Response of power detector

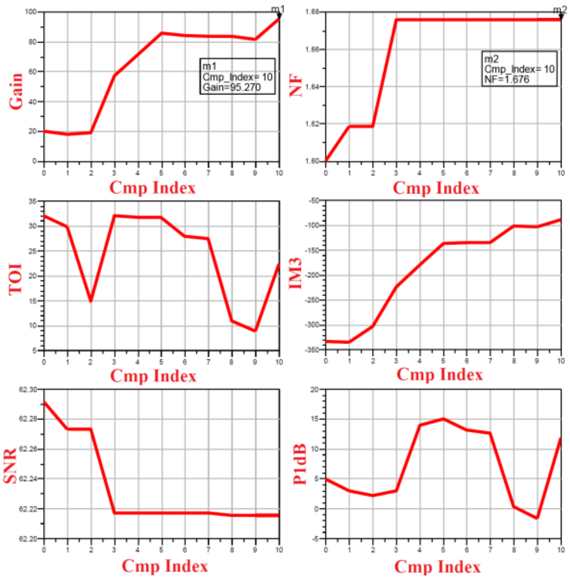

Fig. 14. Specifications of designed receiver

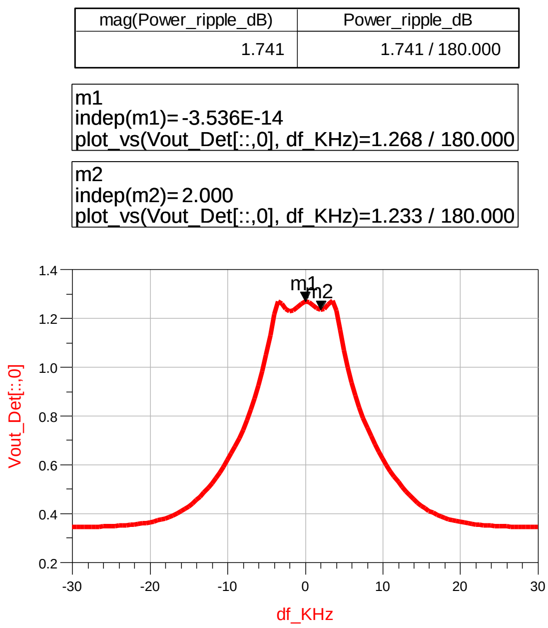

Fig. 15. Voltage level of power detector

In Fig. 15 the output response (voltage level of output of power detector) is plotted relative to the carrier frequency shift. In this simulation, the carrier power is considered constant. It is observed that the response is very similar to response of IF2 filters. The amount of output ripple, carrier frequency shift in the system pass-band is about 1.7 dB that occurs between 2 KHz.

3- SATELLITE SIGNAL BEACON MEASUREMENT

The experimental site was at Tehran, ICT Research Center (ITRC). Description of the measurement site is presented in Table 2. The receiver antenna is pointed toward IS-15(INTELSAT 15), located at 85.2◦ E. The IS-15 is a 3-axis stabilized satellite with zero momentum system and has two 2.3 m deployable dual-grid reflectors and one 1.4 m deck-mounted antenna. The foot print of IS-15 is for Middle East, Indian Ocean and Russia at Ku band.

TABLE 2. SITE CHARACTERISTICS.

Site Parameter	Specification
Earth station location	51.38^0 E , 35.73^0 N
Satellite Position	85.14^0
True North Azimuth	131.12^0
Satellite Elevation	35.40^0
Distance to satellite	38151.435 km
Beacon Frequency	10.951 GHz, 11.451 GHz
Satellite ERIP	42.9 – 56.7 dBW

As mentioned in introduction, one of the most important technics used for satellite wave propagation studies is satellite beacon signal measurement. The beacon signal is a reference signal with fixed frequency, power and without modulation that is sent usually by satellites. This signal usually has its own specific transponder or in some cases is sent between satellite transponder. The frequency plan of INTELSAT 15 is shown in Fig. 16. As mentioned in Table. 2, there are two signal beacons; 10.951 GHz, 11.451 GHz.

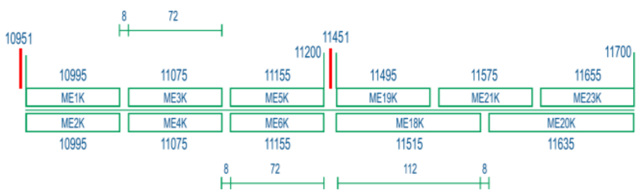

Fig. 16. Frequency plan of Intelsat 15 and two beacon frequencies[22]

The mounted measurement setup has two different sections; the signal beacon measurement system and weather measurement system. The block diagram of the experimental system at ITRC is shown in Fig. 1. Also the characteristics of measurement setup using spectrum analyzer with VSAT systems are presented in Table 3.

TABLE 3. EXPERIMENTAL MEASUREMENT SITE CHARACTERISTICS

Antenna	
Antenna Diameter	1.8 m
Gain (± 0.2 dB)	Rx: 45.0 dBi, Tx: 46.5 dBi
Horn/OMT/TRF	39^0
Insertion loss	Rx: 0.4 dB Max Tx: 0.2 dB Max
Return loss	Rx: 14.0 dB Min. Tx: 17.7 dB Min.
Isolation between two ports	Rx: 35 dB Min. Tx: 65 dB Min. @ 13.75 - 14.0 GHz 75 dB Min. @ 14.0 - 14.5 GHz
LNB	
Input frequency	10.95 ~ 11.7 GHz
Output frequency	950 ~ 1700 MHz
LO frequency	10 GHz
Input Waveguide	WR-75
Gain	50 dB
Gain deviation with temp.	± 2 dB
Noise Figure	0.7 dB (Typ.) 1.0 (Max.)
Output Power	0 dBm (Min.)
Output Connector	F-Type
VSAT router	
Frequency range (Rx, Tx)	950-1700 MHz
Modulation	QPSK, BPSK
RF Power	Rx: -35 to +7 dBm , Tx: -65 to +0 dBm

A programmable data logger is used and programmed to record the rain rate data.

The measurement of beacon signal level is done by a spectrum analyzer. The output signal of the receiver was connected to a spectrum analyzer which was interface to the personal computer via GP-IB (Fig. 17).

Automatic weather station was used in this research for measuring climate change. In this station the data of temperature, air pressure, humidity, wind speed and direction can also be measured. To measure the effects of rain on satellite link, a tipping bucket rain gauge with 200 cm^2 area of rain collector aperture and calibration of 0.1 mm of rainfall per tip was installed at ITRC. The range of measurement in rain gauge is 0-15 mm/min which is adequate for different rain rate in ITRC location.

The Automatic weather station and its rain gauge have its programmable data logger. The clock of the data logger was synchronized with the PC (personal computer) which was connected via RS-458. The measurement setup did not neglect any rain event.

As mentioned, a PC is used to control the measurement process. The first satellite propagation study measurement setup at ITRC and its position are shown in Figs. 19 and 20.

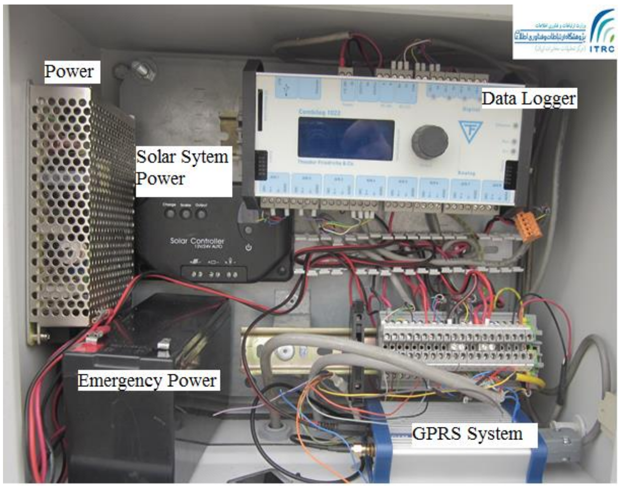

Fig. 17. Automatic Weather Station

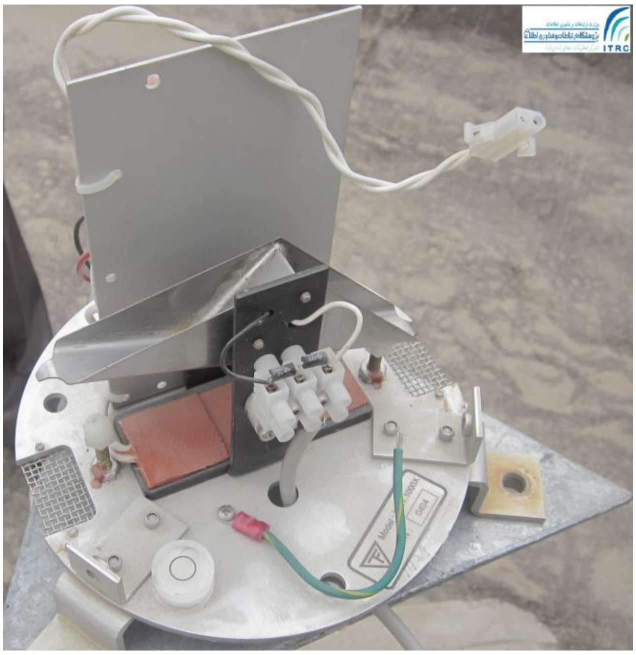

Fig. 18. Applied Automatic Rain Gauge

Fig. 19. The first satellite propagation study measurement setup at ITRC

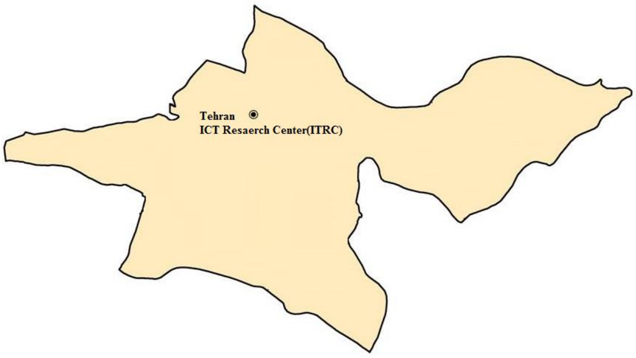

Fig. 20. Position of the mounted measurement setup at ITRC, Tehran

3-1 ATTENUATION DUE TO RAIN, MEASUREMENT AND DISCUSSION

The attenuation (***A***) has a relation with rate of precipitation (***R***). Distribution of the droplets either must be measured, or based on statistical parameters is assumed to obtain attenuation for satellite link through rain events (Fig. 18). For practical calculations the specific attenuation (dB/km) of an electromagnetic wave propagating through rain with intensity ***R*** (mm/h) can be calculated using (1),

$$A = aR^b \tag{1}$$

where ***a*** and ***b*** are dependent on frequency as well as polarization and temperature and can be found in ITU-R Recommendation P.838 [6]. Dependency on temperature is for variation of water dielectric constant with temperature. The detail of this and empirical value for ***a*** and ***b*** can be find in [6].

When specific attenuation is known, attenuation through rain can be calculated by multiplying the specific attenuation and effective path length through rain. For given location and elevation angle, this parameter can either be found from simultaneous measurement of rain attenuation and rainfall rate.

Rain intensity for different percentages of time can either be acquired from local measurement.

3-2 MEASURED SIGNAL LEVEL AND RAIN INTENSITY

Within the period of January to June 2012, beacon signal level and rain rate, were recorded, collected and analyzed during propagation and communication time. By subtracting a reference level from the measured received signal level, the rain attenuation was obtained.

In the period of measurement (six month), we had 53 rainy days. In 12 days, rain rate was over 10 mm/h and in the April of 2012 rain rate was about 50 mm/h.

It should be note that the reference level is obtained by averaging the entire received signal level data on each month during sunny day. Here the rain rate and the rain attenuation were averaged over every one minute. The relation between rain attenuation and rain rate is presented in Fig. 21. After curve fitting, the value of the ***a*** and ***b*** in equation (1) was found a=0.314 and b=1.869 (Fig. 22). In Fig. 22, the dots are obtained by directly rain attenuation vs. rain rate. The solid line is the curve fitting obtained by fitting rain rate vs. rain attenuation, and finally the dash line is ITU-R model. Compression between measured rain attenuation and ITU-R model is presented in Fig. 23.

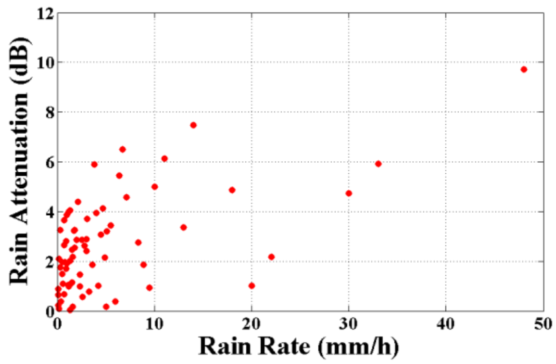

Fig. 21. Measured rain attenuation vs. rain rate at ITRC

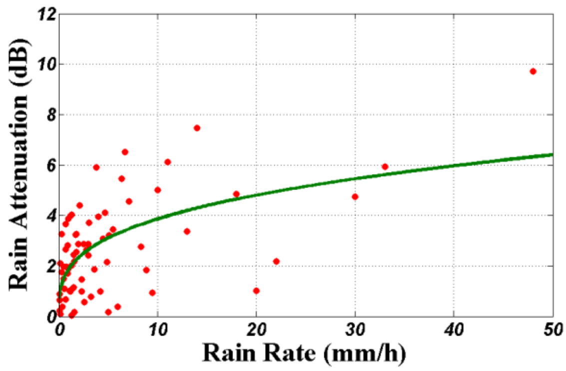

Fig. 22. Curve fitting for measured rain attenuation and rain rate at ITRC

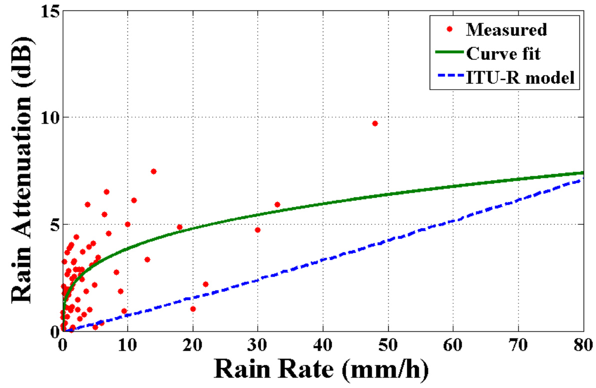

Fig. 23. Comparison between measured rain attenuation and ITU-R model

According to the Fig. 23, ITU-R model and measured data have some differences and there are some deviations from the norm between rain attenuation and rain rate. It should be considered that when the rain rate increases, the difference between measured data and ITU-R model is decreased.

These results were predictable because according to the published theoretical and experimental studies of rain attenuation, it should be considered that using global rain attenuation prediction models is not suitable solution in local satellite link design. In the other hand, detailed satellite wave propagation study at local points is necessary. However there are some techniques, such as site diversity, to improve link availability.

Also the measured rain intensity at the local point is not superseded of the rain intensity along the propagation path which is affected by rain. There are several parameters influencing the rain along the propagation path such as size, distribution, rain drop shape, rain rate, wind speed, temperature, and direction of rain. These parameters will affect the effects of rain along the propagation path. Global models such as ITU-R model are not applicable to regional areas and finally have not good accuracy.

It is necessary to measure, collect and record much more data for a long period of time and at local neighborhood regions in order to yield a stable and reliable relationship between rain attenuation and rain intensity.

4- IMPLEMENTATION OF PROPAGATION SOFTWARE

Satellite wave propagation experimental studies essentially need to a software to gather and record the signal and weather data simultaneously. For this purpose Radio Communication Group designed and implemented the propagation software. The software main core is the signal level measurement unit, presented in Fig. 24. This core consists of different phenomena affecting the signal The software's submenus are shown from Fig. 25 to Fig. 30.

Fig. 24. The overall structure of software for satellite broadcast

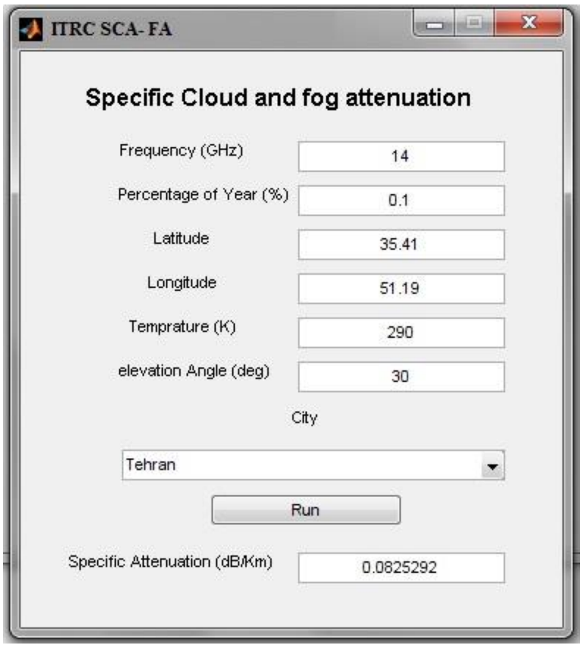

Fig. 25. Specific cloud and fog attenuation menu

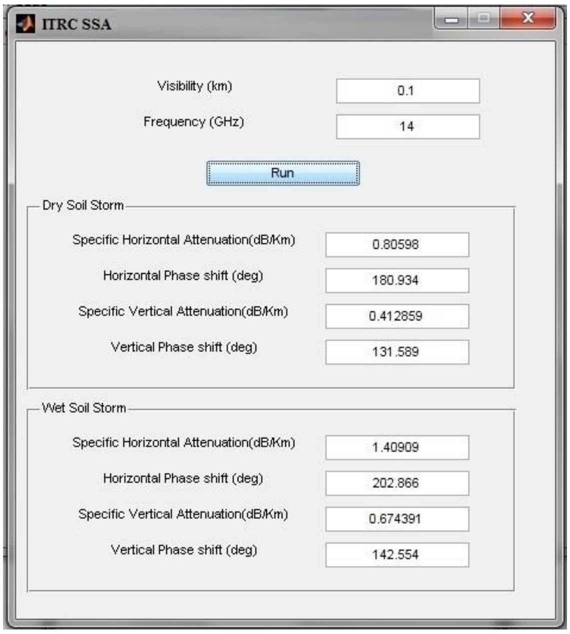

Fig. 26. Soil storm attenuation menu

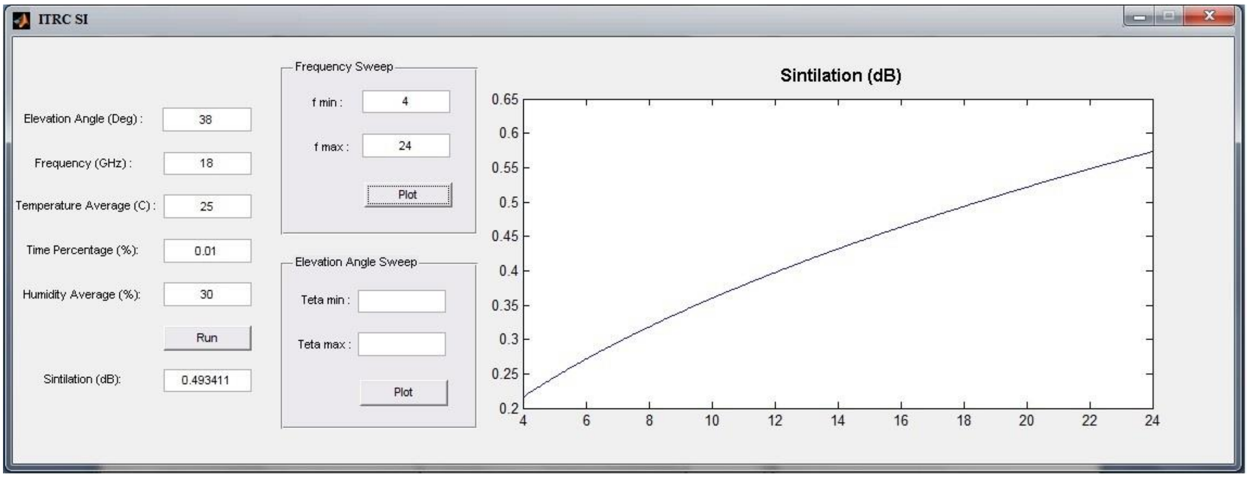

Fig. 27. Scintillation effect menu

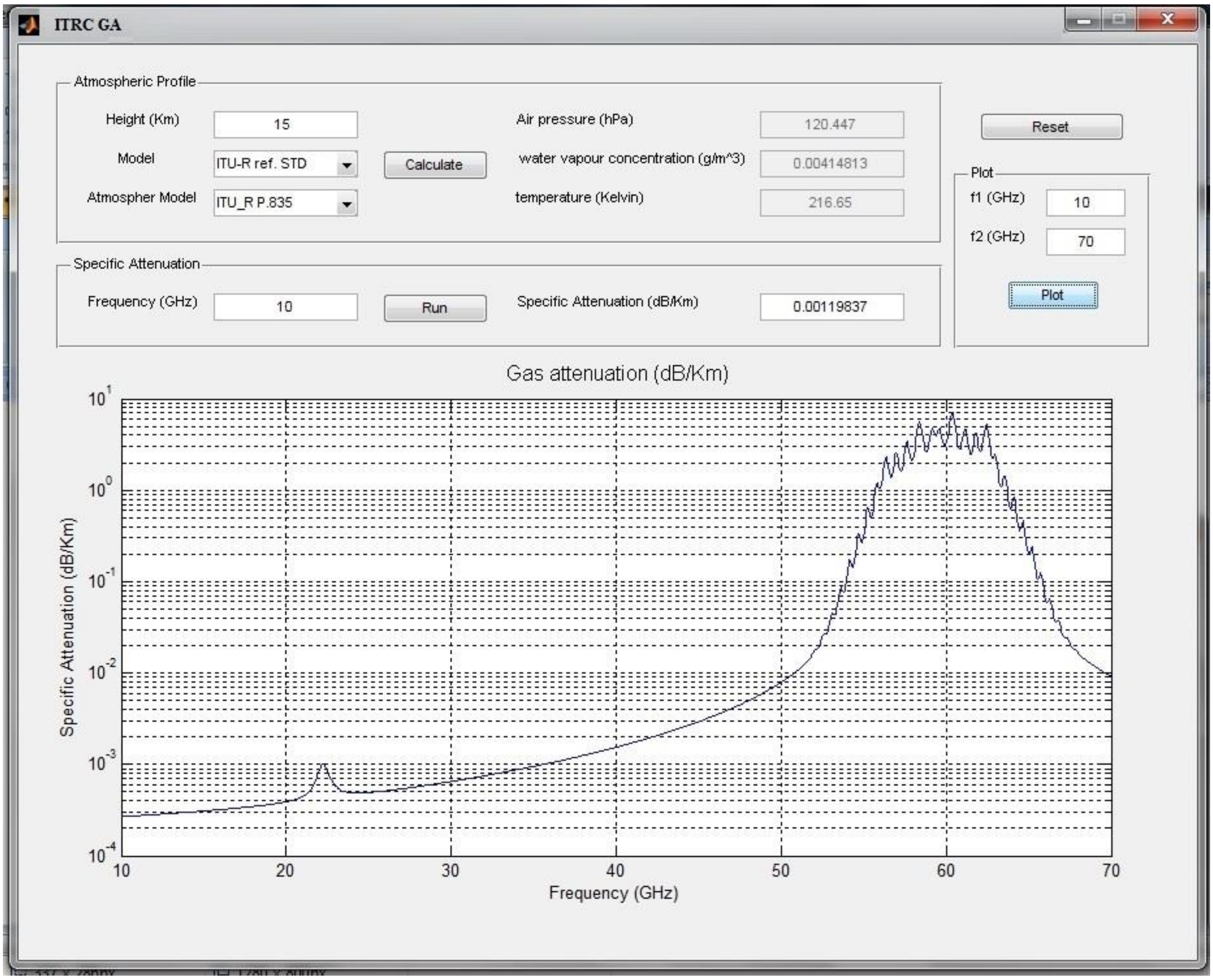

Fig. 28. Gas attenuation menu

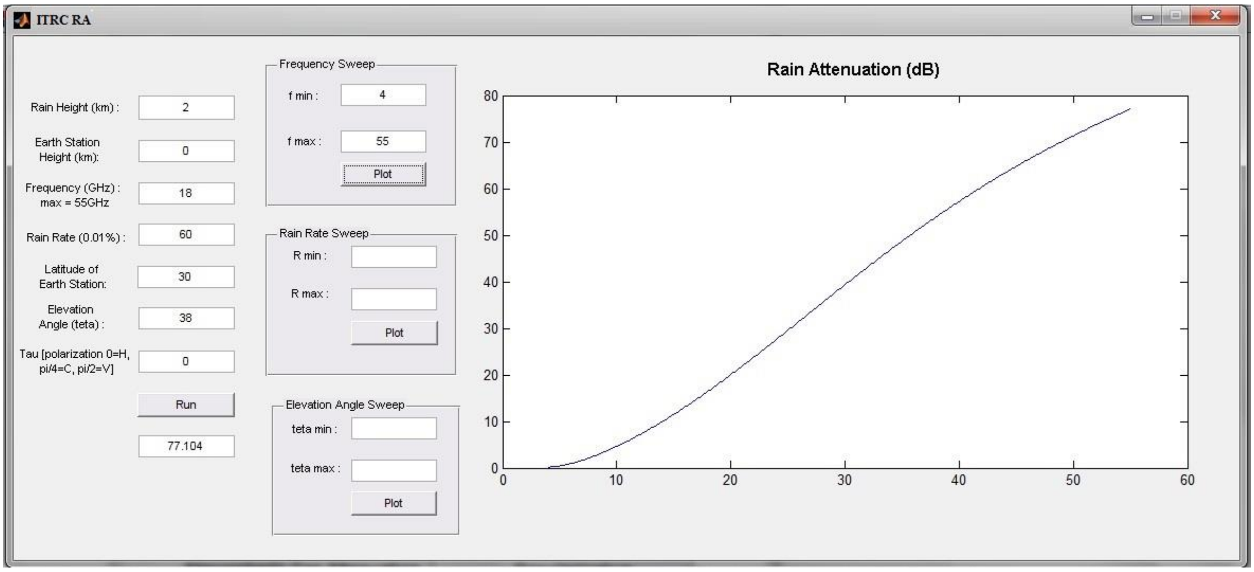

Fig. 29. Rain attenuation menu

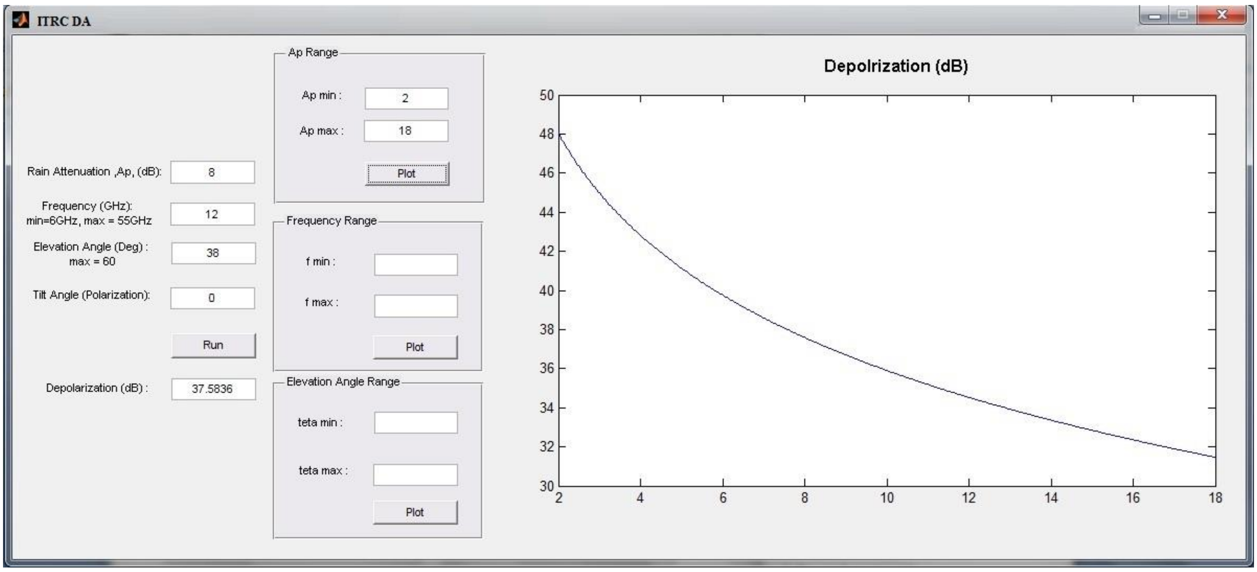

Fig. 30. Depolarization effect menu

5- CONCLUSION

In this paper, design and simulation of beacon signal receiver has been presented. Beacon signal due to low transmitter power and small receiver bandwidth, requires high precision and low cost receiver. Using a standard LNB that is out of signal receiver, and employing appropriate parts and filters can help to increase precision of the receiver and to reduce the cost of manufacturing.

Also, description of the first satellite propagation study measurement setup at ITRC has been presented. The results of six months measurement of rain rate and rain attenuation has been delivered. Also the relation of rain attenuation versus rain intensity on radio wave propagation in Ku-band has been shown. Comparison between measured rain attenuation and ITU-R model has been presented and reasons of the different results has been delivered. According to the published theoretical and experimental studies of rain attenuation, it should be considered that using global rain attenuation prediction models is not suitable solution in local satellite link design. In the other hand, a detailed satellite wave propagation study at local points is necessary. However there are some techniques, such as site diversity, to improve link availability.

Finally, the description of the implemented propagation software and its sub components are presented.

ACKNOWLEDGMENT

This work is supported by ICT Research Centre (ITRC).

REFERENCES

[1] Allnutt, J. E., “Satellite-to-ground radio wave propagation”, IEE Electromagnetic Waves Series 29, Peter Peregrines Ltd., 2011.

[2] Gunes, M., Gunes, F. and Dimiller, K., “Development of a Climatic Map of Attenuation by Rainfall for Turkey”, Proceedings of the 7th Mediterranean Electro Technology Conference, pp. 383-386, 1994.

[3] Mandeep, Jit, “Comparison Of Rain Attenuation Prediction Models With Measurements Results Of Rainfall Rate”, Journal of Applied Sciences Research, Vol. 9, Issue 13, pp. 6217-6220, Dec. 2013.

[4] Al-Jumaily, A.H.J., Sali, A. , Ismail, A. ; Mandeep, J.S. and more authors, “Performance analysis of rain attenuation at Ku-band in Malaysia”, IEEE International Conference on Space Science and Communication (Icon Space), Dept. of Comput. & Commun. Syst. Eng., Univ. Putra Malaysia, Serdang, Malaysia, 2013.

[5] Nalinggam, R. ; Islam, M.T. and more authors, “Development of rain attenuation model for Southeast Asia equatorial climate”, IET, communications, Sch. of Electr. & Electron. Eng., Univ. Sains Malaysia (USM), Nibong Tebal, Malaysia, 2013.

[6] Recommendation ITU-R P.838-3, “Specific attenuation model for rain for use in prediction methods”, P Series, International Telecommunication Union, Geneva, Switzerland, 2005.

[7] M. Yamamoto, “New development of digital beacon receiver based on GNU Radio” 12 th International Symposium on Equatorial Aeronomy (ISEA-12)May 18-24, Crete, Greece, 2008.

[8] Gardner, F. M., “Phase lock Techniques”, John Willey & Sons, 1966.

[9] C. J. Kikkert,“A digital signal processing based Ka band Satellite Beacon Receiver/Radiometer,” Signal Processing and Communication Systems, ICSPCS 2008.

[10] Kikkert, C. J., “A digital signal processing based Ka band satellite beacon receiver, Information, Communications & Signal Processing,” 6th International Conference on ICECS 08, 2008.

[11] Crane R. K., and et al, “ACTS Propagation Experiment: Experiment Design, Calibration, and Data Preparation and Archival,” Proc. of the IEEE, Vol. 85, No. 6, 1997.

[12] Yamamoto M., “Digital beacon receiver for ionospheric TEC measurement,” E-LETTER, Earth Planets Space, 60, e21–e24, 2008.

[13] Gonzalez, G., Microwave Transistor Amplifiers: Analysis and Design, 2nd Edition, 1996.

[14] www.norsat.com.

[15] http://www.analog.com.

[16] Bahri, R., Yarmohammadi, H., Bashirzadeh , S., Kiaei ,F. and Rahmani ,M.,”Providing software and the specifications of the standard software to Estimate the effects of atmospheric phenomena on satellite links in the country”, 19 th ICEE conference, Ferdowsi University, Mashhad, Iran, 2013.

[17] Yarmohammadi, H., Bahri, R., Jesri, R. “Design and Simulation of Satellite signal receiver bacon for use in the study of wave propagation in the bands”, Satellites for Sustainable Development conference, Amirkabir University, 2012

[18] Yarmohammadi, H., Bahri, R., H. Maftouli, “Installation of the first pilot measurement of Ku-band satellite broadcast using satellite beacon signal GEO in country”, Satellites for Sustainable Development conference, Amirkabir University, 2012

[19] Khosravi, M., Bahri, R. and Moghadasi, M.,“

Localization Ku and Ka band prediction models of satellite broadcasting in Iran", Satellites for Sustainable Development conference, Amirkabir University, 2012.

[20] Kiaei , F., Bahri , R., Kiaei ,M., Azid , T., " A MCMC Bayesian Approach to Binary Logistic Model for Ka-band Propagation Effect by Rain Over Iran", Loughborough Antennas & Propagation Conference, Loughborough, UK, 2012

[21] Bahri , R., Kiaei ,F, H., Maftouli, Moghadasi , M. Khosravi, M.,"Satellte wave propagation wrkshop", 6 th IST Conf., ITRC, 2012.

[22] http://www.satsig.net/eut2beac.htm