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Analysis Ofhf Propagation Reception At ZS1HMO Beacon Receiver Station

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Abstract

In this paper a sample High frequency (HF) beacon measurements that are part of the larger archive that is being collected at the beacon monitoring station in Hermanus, South Africa, ZS1HMO (34.42°S, 19.22°E) are presented. Using the NCDXF/IARU International Beacon Project, beacon signal observations from Africa, Asia, Australia, Europe, North America and South America wereanalysed. The observationsshow the variation in signal strength received at ZS1HMO from the six continents considered at each beacon frequency (14.10, 18.11, 21.15, 24.93 and 28.20 MHz). With the aid of HF propagation prediction software, ICEPAC, the predicted signal to noise ratio (SNR) values were compared with beacon SNR measurements gathered by the ZS1HMO monitoring stationfor a regional HF link, Ruaraka to Hermanus.

Keywords– *HF propagation, beacon, SNR, ICEPAC, prediction model*

1. Introduction

HF radio propagation depends upon the ability of the ionosphere to return the radio signals back to Earth. Effective command, control and communication require a comprehensive combination of alternative communicationslinks, one of which is HF [1].Radio communication in the HF band is of relevance to military and humanitarian organisations, as well as amateur radio operators, particularly during emergency situations where the normal power and communications infrastructure may have failed. This communication technique primarily makes use of waves transmitted at variable angles from the ground, such that terrain obstructions have little or no influence on the received SNR[1,2]. Appropriate choice of operating frequency is also important for effective HF radio communication. HF propagation iswell known to be appreciably influenced by the large-scale inhomogeneous structures in the electron concentration distribution both in the vertical and horizontal directions within the Earth's ionosphere [3].HF radio wave propagation between two locations on the Earth's surface takes place via a combination of reflections from the ionospheric layers and the Earth's surface[3-5]. This refraction of HF signals back to Earth via the ionosphere gives rise to intercontinental HF radio communication and therefore allows the reception of international beacon signals. Since there are occasional and largely unpredictable disturbances of the ionosphere that interfere with HF communications, HF propagation predictionmodels are often required to support system design, service planning and frequency management. These propagation predictions allow planning and selection of antennas, as well asadequate frequencies and exploitation schedules[4,5]. Some propagation models operate in real-time or near real-time and they may even directly advise on a course ofaction which would improve system performance.HF propagation predictionmodels predict the expected performance of HF communicationsbased on ionospheric variations due to sunspot activities, hours of the day and geographiclocation. However, unlike these models, the NCDXF/IARU International Beacon Project (IBP) assessesthe current condition of the ionosphere by real-time SNR measurements.This paper presents real-time beacon SNR measurements obtained fromthe IBP international radio network operating on14.10, 18.11, 21.15, 24.93 and 28.20 MHz.The receiver station (ZS1HMO) is situated in Hermanus, South Africa. The SNR measurements were also compared with ICEPAC (Ionospheric Communications Enhanced Profile Analysis and Circuit) model predictions as an application of the real-time beacon data in validating the performance of propagation prediction models over the Southern African region.ICEPAC was selected for this investigation because of readilyavailable literature on its use and the range of output parameters[6, 7].In this paper, the 18 IBP beacon transmitters and the receiving station are referred to by theircall signs. Figure 1 shows the locations of the IBP beacons around the world as well as the ZS1HMO monitoring station in Hermanus.The geographic coordinates and the distances between the beacon transmitter stations and the receiver station are given in Table 1 for thesix HF communication links considered in this paper.

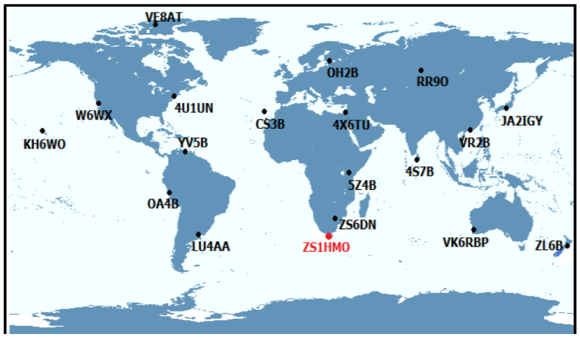

Figure 1.Locations of the IBP beacons around the world and the ZS1HMO monitoring station in Hermanus, South Africa

Table 1. Geographic coordinates for beacon transmitters and receiving station

Transmitting Beacon	Coordinates	Distance to ZS1HMO (km)
ZS6DN (Pretoria, South Africa)	25.75°S, 28.17°E	1 291
VR2B (Hong Kong, China)	22.27°N, 114.15°E	11 813
VK6RBP (Rolystone, Australia)	32.10°S, 116.05°E	8 611
CS3B (Santo da Serra, Madeira)	32.72°N, 16.8°W	8 358
4U1UN (New York, USA)	40.75°N, 73.97°W	12 653
OA4B (Lima, Peru)	12.07°S, 76.95°W	9 807

2. Signal Measurement System

2.1Beacon Transmitters

The NCDXF/IARU International Beacon Project (IBP) is a network of HF radio beaconsaround the world operating continuously, transmitting onfive HF bands, namely: 14.10, 18.11, 21.15, 24.93 and 28.20 MHz. The beaconstransmit according to a known timing sequence and calibrated power levels. Eachtransmission consists of the call sign of the beacon sent at 22 words per minutefollowed by four one-second dashes. The call sign and the first dash are sent at100 W. The remaining three dashes are sent at 10, 1 and 0.1 W, stepping downward inpower with each dash [8]. With an accurate clock it is possible to deduce the transmitting beacon at any given time.A weak beacon signal may also indicate a path with excellent propagation forstations using higher power and directive antennas, since the beacons are running100 W to a vertical antenna.

2.2 Receiver Station

The ZS1HMO HF beacon receiving station uses a super-heterodyne receiver with the automatic gain control (AGC) disabled. The demodulated audio signal is sampled by a computer sound card sound card. The receiver has been calibrated using a low-power crystal oscillator and also a commercial signal generator. The receiving station uses the MFJ-1778 G5RV multiband antenna installed in an inverted V configuration with an apex angle of 108° [9]. Faros 1.3 software was interfaced with a computer and thenused to automatically monitor the beacon signals.Faros software filters and recognises the beacon signals out of noise.Three parameters are recorded: the SNR, QSB index (the percentageof time on a scale of 0 - 100 %, during which the signal is below thenoise level) and the propagation delay of the signal. In addition,Faros calculates the “evidence” i.e. the measure of probability that thereceived signal was transmitted by the IBP beacon, on a logarithmic scalewith detection threshold of evidence equal to 1 [8].

2.3 HF Propagation modelling

HF propagation predictions in this paper were done usingICEPAC version 05.0119W. Method 20 (complete system performance) was used together with the CCIR coefficients. The sporadic-E model was turned off because the model has not been validated and its use may lead to overly optimistic results [6]. The predictedSNR values at the receiver location are computed by taking into consideration the ionospheric propagation conditions, as well as the atmospheric and local man-made site noise levels [7].

3. Results and Discussion

In this paper the parameter SNR is used as the measure of the quality of the communication over the desired communication link. It should be noted that the receiver monitoring station (ZS1HMO) is located in Hermanus, South Africa and therefore, all the results and conclusions presented in this paper are with reference to propagation to Hermanus, South Africa.

3.1 Analysis of beacon reception

The basiccommunications requirement is to provide a SNR that is large enough for the intendedmode of operation [10,11,13].Monitoring IBP beacons provides the opportunity to observe how HF propagation varies by considering the strength of the signal received relative to the noise level at the receiver site. Figures 2 - 7 show beacon observations for three consecutive days, namely, 6, 7 and 8 January 2009 from the five continents considered: Africa, Asia, Australia, Europe, North America and South America (see Table 1).

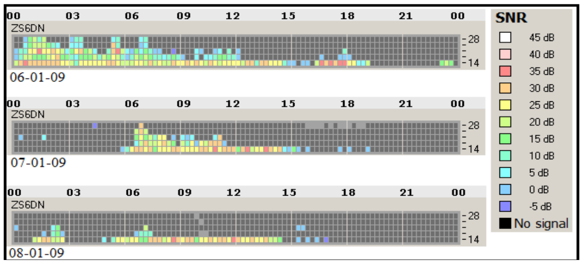

Figure 2Reception of beacon signals from ZS6DN, Pretoria, South Africa

Figure 2 shows signal reception for the ZS6DN - ZS1HMO link. The ZS6DN beacon is the closest of all the IBP beacons to the ZS1HMO monitoring station. In Figure 2, daytime propagation shows SNR values reaching their lowest at sunset, approximately 16h00 UT, in step with the reduction of ionisation in the ionosphere which occurs with low solar radiation as sunset approaches [5, 9, 11]. Strong night time multiband propagation openings with SNR values of up to 40 dB were observed between 00h00 UT and 04h00 UT on 06-01-09. This was probably the result of reflection by sporadic E (Es) layers at the link midpoint. The SNR levels were high and occurred for longer durations, suggesting that the Es clouds could have had larger horizontal axes [14]. The opening of the 28.2 MHz band is usually linked to sporadic E activity, which can support transmission links ranging from about 650 km to 2 100 km for single hop propagation [5,13].

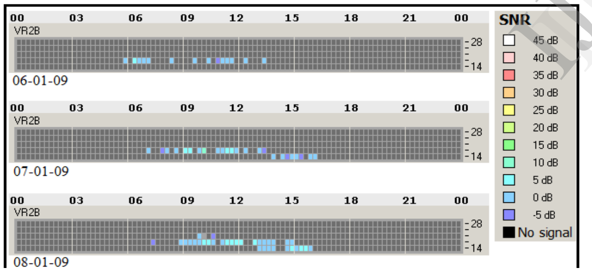

Figure 3.Reception of beacon signals from VR2B, Hong Kong

Figure 3 showssignal reception for the VR2B to ZS1HMO.From Figure 3, it is shown that from 06-01-09 to 08-01-09, reception of beacon signals from VR2B occurs during local day time, 06h00 UT - 16h00 UT. The reception of the VR2B beacon signals is characterised by low SNR values of less than 10 dB. Propagation is through 14.1 MHz and 18.11 MHz with very short weak openings on 21.15 MHz.

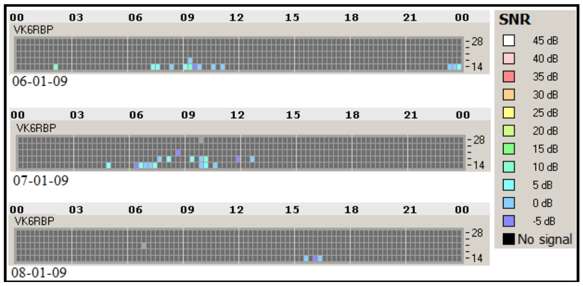

Figure 4.Reception of beacon signals from VK6RBP, Rolystone, Australia

Figure 4 shows signal reception for the VK6RBP - ZS1HMO link.From Figure 4, significant beacon reception occurred between 06h00 UT and 12h00 UT on 06-01-09 and 07-01-09. Weak signals were received from Australia on 14.10 MHz, 18.11 MHz and 21.15 MHz.

Figure 5 shows signal reception for theCS3B - ZS1HMO link.From Figure 5, the reception of beacon signals from CS3B was through 14.1 MHz, 18.11 MHz and 21.15 MHz.The received signal quality was generally low, less than 15dB. The signal reception occurred generally between 12h00 UT and 20h00 UT, which corresponds to local late afternoon and early night fall in Hermanus.

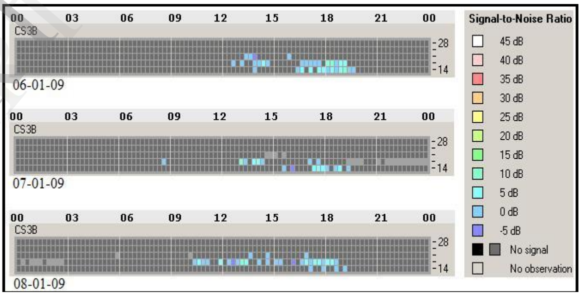

Figure 5.Reception of beacon signals from CS3B, Santo da Serra, Madeira

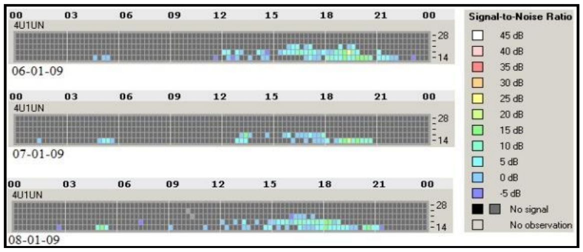

Figure 6.Reception of beacon signals from 4U1UN, New York, USA

The results shown in Figure 6 are for the 4U1UN to ZS1HMOlink. From Figure 6, the reception of beacon signals from 4U1UN generally occurred through 14.1 MHz, 18.11 MHz and 21.15 MHz. Short band openings were witnessed during the local morning hours, 05h00 UT to 06h00 UT, and wider openings on 14.1 MHz, 18.11 MHz and 21.15 MHz during the local late afternoon hours.

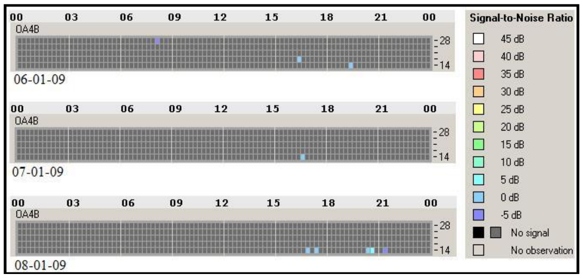

Figure 7.Reception of beacon signals from OA4B, Lima, Peru

Figure 7 shows SNR measurements for the link from OA4B to ZS1HMO. Propagation between Lima and Hermanus was very poor. Band openings on 14.1 MHz, 18.11 MHz and 28.2 MHz were very short, with weak very SNR of less than 5 dB.

The SNR measurements presented in Figures 2-7 show that when HF radio communication takes place through sky wave propagation, the received signal strength is not constant but vary with time due to the fluctuations in ionospheric conditions. Reception of signals from ZS6DN was characterised by high SNR values and wide band openings whilst reception of signals from South America, North America, Asia and Europe was characterised by low SNR values and shorter band openings. This could have been a result of high signal absorption over such longercommunication links[11]. With long distance propagation, the net propagation link can be a complicated summation of various hops including different ionospheric layers. This may then result in increased signal loss during reflections between hops [11,12]. Propagation between ZS1HMO and western locations such as OA4B (Lima, South America) show very weak SNR values and erratic band openings as shown in Figure 7. This could be due to differences in ionospheric behaviour which occurs when one part of the link is in daytime and the other in night time, and hence resulting in signals suffering excessive absorption [13,14]. Apart from the regular and irregular ionospheric variations, transmitter (Tx) and receiver (Rx) antenna heights, Tx and Rx antenna gain, Tx power and man-made noise at the Rx site may also have a significant effect on beacon signal reception at the ZS1HMO monitoring station. Apparently, greater antenna height can be an advantage at certain times of the day for some communication links and alsounder certain conditions when the lowest useable frequency (LUF) is just below a band. High antennas can also widen the propagation window enough to make radio communication more likely than with low antennas [13].

3.2Comparison between measured and predicted SNR

Figures 8 and 9 show the comparison between ICEPAC and beacon SNR measurements for selected individual days in September 2009 on 14.1 MHz and 18.11 MHz for the 5Z4B - ZS1HMO (Kenya to South Africa) link.

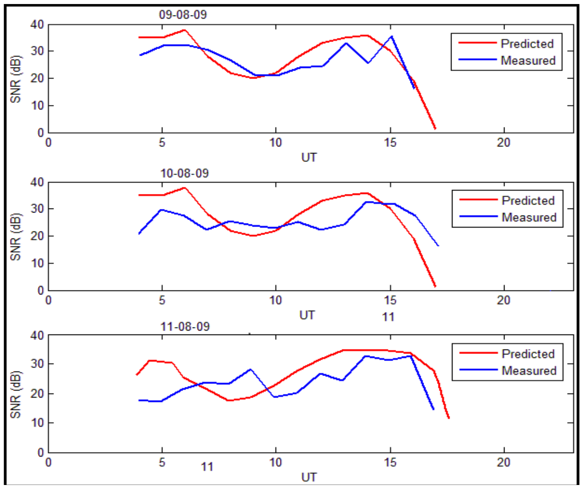

Figure 8.Comparison of predicted and measured SNR for 9, 10, 11 September 2009 on 14.10 MHz

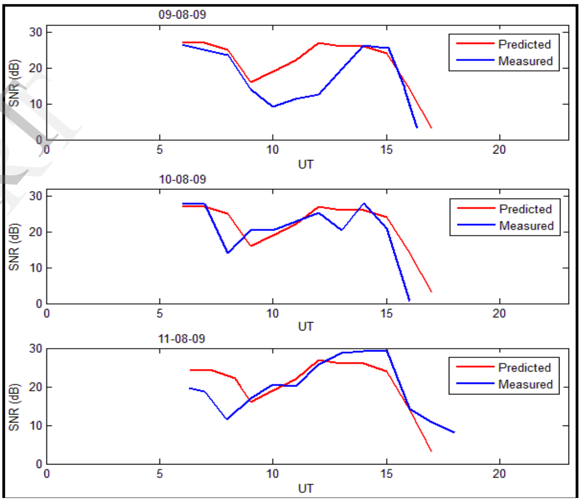

Figure 9Comparison of predicted and measured SNR for 9, 10, 11 September 2009 on 18.11 MHz

In Figures 8 and 9, the measured and predicted SNR often decreased to levels below the noise level, hencedata points for SNR < 0 dB were not plotted.The comparisons between ICEPAC predictions and beacon SNR measurements show that the SNR parameter has a diurnal dependence and a variability that is due to changing ionospheric conditions. From these Figures 8 and 9, it can be noted that the predicted SNR curves do not exactly match the measured SNR curves.This can be attributed to weak ICEPAC prediction of communication link performance [6,7,17]. Comparisons on 14.10 MHz and 18.11 MHz are characterised by significant deviations between predicted and measured SNR values. These deviationsmay be due to the fact that ICEPAC predictions are computed based upon median data, therefore resulting in median output parameters since ionospheric conditions are constantly changing and probably deviating from the median conditions[15,17].

4. Conclusion

SNR measurements from the IBP network of beacon transmitters were analysed and compared with ICEPAC predictions.The results presented in this paper show interesting characteristics of HF radio wave propagation and its dependence on the behaviour of the ionosphere.The preliminary results on the comparison between beacon SNR measurements and ICEPAC SNR model predictions show the potential use of the propagation data gathered by the ZS1HMO station in validating the performance of HF propagation prediction models over the Southern African region.

5. References

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