HADMÉRNÖK

VIII. Évfolyam 1. szám - 2013. március

Róbert Kovács
kovacs.robert@nbsz.gov.hu

THE HISTORY OF FIRST HIGH FREQUENCY DIVERSITY RECEPTION TECHNIQUES

Abstract

In the early 1900s, as improvement of radiocommunications technology had provided solutions for longwave and later, shortwave communications links, it was inevitable to discover and investigate the propagation anomalies experienced in high frequency bands. The recognition of fading behaviour and its independent characteristics in space, time and polarization straightly led to a development of special receiving techniques using more than one receiver inputs simultaneously and combining them to achieve improvements in signal quality, called diversity. The pioneer's way from the unique technical solutions to receiver prototypes ready for mass production is introduced in this article.

Ahogyan az 1900-as évek elején a rádiókommunikációs technológia fejlődése megoldásokat kezdett kínálni a hosszúhullámú, majd később rövidhullámú összeköttetések számára, elkerülhetetlenné vált a terjedési anomáliák felfedezése és tanulmányozása a rövidhullámú sávokban. A fading jelenségének, valamint tér-, idő- és polarizációfüggetlen viselkedésének felismerése, a vett jel minőségének javítása érdekében egyenes utat képezett az egyidejűleg több vételi ágat és azok közösítését alkalmazó, diverzitinek nevezett vételtechnikai módszer kifejlődéséhez. A cikk az egyedi műszaki megoldásoktól a sorozatgyártásra alkalmas prototípusokig vezető utat mutatja be.

Keywords: *space diversity, multi-path propagation, fading, XG1E receiver, DD-1 Skyrider receiver ~ térdiverziti, többutas terjedés, féding, XG1E vevő, DD-1 Skyrider vevő*

1. INTRODUCTION

Different layer heights of the ionosphere have always resulted in a severe multi-path radio propagation circumstances. Especially in high frequency band different types of fading occur. The transmitted skywave signals follow different paths through the ionosphere differing in direction and length. Sometimes these deep fades may last for half a minute or more, causing the signal received to drop below noise level, thus a long stream of information flow may be lost until the signal level increases above noise level again. Besides that, another type of fading also occurs as a result of several waves from the same transmitter are refracted through the ionosphere, causing distortion on signals. The refraction of signals leads to additional phenomena, as the radio waves suffer rotation through ionosphere producing changes in their polarization.

The first theorethical and practical studies of the phenomena above are almost as old as commercial and amateur HF radiocommunications and were firstly executed on an experimental basis as early as the first quarter of the twentieth century. This work is intented to give a historical overview of results acheived at that early age in recognising and identifying the phenomena and finding the initial technical solutions to mitigate them with a receiver techniques called diversity reception.

2. THE PIONEER AGE OF DIVERSITY RECEPTION

The story of diversity reception started in the early 1920s, when two engineers working for the Radio Corporation of America (RCA), Harold. Henry Beverage and his associate, H. O. Peterson, known for their pioneering research in early radio, began investigating the circumstances of fading. Their interest focused on the actual happenings of the signal received through fading channel. The two engineers were monitoring and comparing the same transmitter signal as received from two different locations simultaneously. They set up experiments with receiving antennas spaced initially some fifteen kilometers apart. By stages, they decreased the separation to only 800 meters away. [1] By monitoring from Peterson's home and from the RCA station site connecting them via telephone line, Beverage and Peterson noted that each station received the same transmitted signal with different fading characteristics. Based on further tests the minimum distance of the receiving antennas was found to be as little as 100 meters. This was the base to invent the space diversity in 1926. [2], [3], [4]

Beverage and Peterson first connected strip-chart recorders to a combination of three antennas and three receivers. The charts showed that the transmitted signal was received at different amplitudes and different phase at the antennas. Searching for the reason of the phenomenon the two engineers speculated that radio waves were being refracted in the ionosphere at different angles and therefore some wave-angles would miss the antenna. They multiplied the number of receiving antennas in order to capture more wave angles, but actually they found the opposite happened. The use of larger antenna arrays caused degradation in fading effect. The two men then theorized that over the horizon radio waves could be simultaneously refracted from different heights in the ionosphere, thus travelling different paths and therefore arriving at the single receiving antenna at slightly different times. They realized that the effect of multiple phases would result in strong fluctuating in the received signal strenght. They also established that since the ionosphere was nearly always in a changing state, fading was always going to be present. To eliminate the negative effect of fading they used receivers with at least a full wavelength of antenna separation and equipped them with separate antennas to provide the necessary isolation. This structure suplemented with the use of second detector made possible to eliminate the effect of phase differences after

converting the signal to audio level. Perfecting the system they were also the firsts to use an operational AVC (Automatic Volume Control) and Tone Keyer, which supported the diversity receiving of CW signals. [2]

Beverage and Peterson, while working at Riverhead, NY, installed the first space diversity stations for reliable, long-distance communication. As a result of these observations, the RCA Diversity Receiving System was developed. [5]. (Figure 2.1)

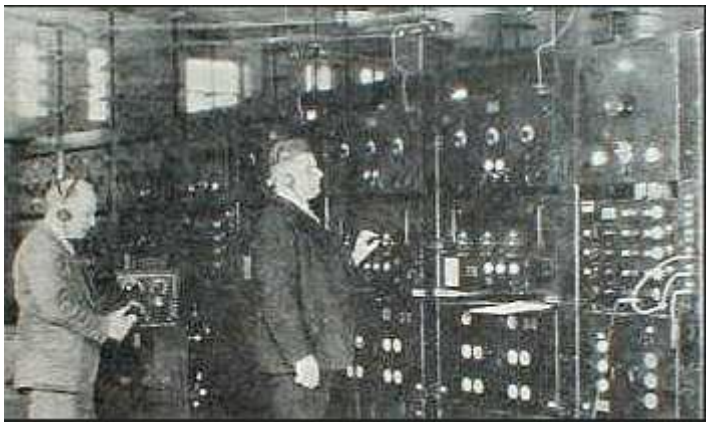

Figure 2.1. H.O. Peterson and H. H. Beverage and their triple diversity HF receiver (1933)
Source: http://www.radioblvd.com/DiversityDD1.html (23/02/13)

By the late twenties, RCA had 41 triple-diversity receivers with associated antenna farm, with 300 meters of separation between antennas installed at Riverhead in communications with 26 different countries. These inventions related to diversity made up the bases of several of Beverage's adopted patents. [6]

By the 1940s, the diversity stations became more sophisticated. RCA had introduced its AR-88 receiver which was adapted to the new triple-diversity receiver, the DR-89 (Navy designation RDM.) These two meter tall racks contained three AR-88 receivers.

Even more complex was the military RCP and RBP-1, also built by RCA for the Navy during World War II. The RCP used double conversion receivers with multiple tuners installed in four racks. The RBP-1 was a dual-triple diversity receiver (six double conversion receivers) that was essentially two RCPs side-by-side. The entire setup weighed not less than about 1500 kgs. The RBP-1s were still in use as late as the 1970s. (Figure 2.2)

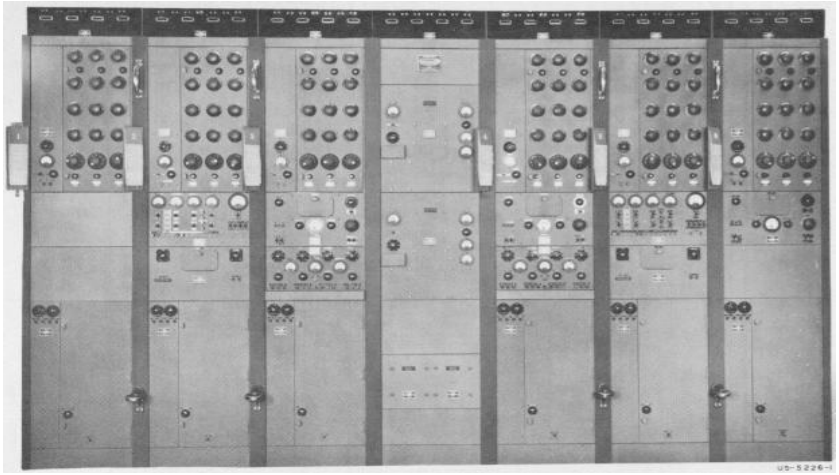

Figure 2.2. The RBP-1 dual-triple diversity HF receiver (1945)
Source: http://www.navy-radio.com/manuals/rbp/rbp-fig1.jpg (23/02/13)

From the beginning of the fifties, besides space diversity the first attempts of frequency diversity were also presented in teletype installations. Presuming that two different frequencies would rarely fade together, in this applications one frequency and receiver was used for „mark" and another set for „space". The Collins Radio Company manufactured about 20.000 receivers of this type for the US Armed Forces under the name R-388 and R-390. [2] , [7] (Figures 2.3 and 2.4.)

Figure 2.3. Collins R-388 HF diversity receiver (1951)
Source: http://www.virhistory.com/navy/rcvrs/r388.htm (23/02/13)

Figure 2.3. Collins R-390 HF diversity receiver (1950)
Source: http://www.radioing.com/collins/rx08.html (23/02/13)

From the early 1940s, if a full wavelength of antenna separation wasn't practical to apply, an initial form of polar diversity also appeared. There are some printed sources available featuring a solution which used both horizontally and vertically oriented antennas for receiving with only one receiver. Using a 400 Hz switching between the antennas the switching gave an additional modulation to the signals that made the use of BFO-s (Bit Frequency Oscillator) redundant.

3. EARLY RADIOAMATEUR APPLICATIONS OF DIVERSITY RECEIVING

Amateur interests in diversity reception waned as World War II loomed in the near future. The expense, the complexity, the space required for antennas all made the results not worth the effort. On CW, there was no obvious benefit to diversity and, in the pre World War II days, most hams were on CW. Amateurs became familiar with the principals of diversity reception by reading various books and magazine articles throughout the twenties and thirties. QST magazine published an article „Short Wave Radio Transmissions and Its Practical Uses Part II". by Chester W. Rice in the August 1927 issue about shortwave uses that mentioned diversity theory and reception. For the avid phone operator, having the equipment to eliminate fading signals and the associated distortion, it must have seemed like a virtual necessity. To the CW operation mode diversity seemed not be worth the effort. After all, CW copy was not that seriously affected by fading. [2]

As John. J Nagle reffered in [9] there was an attempt of Carll Roland, using two antennas and shortwave broadcast receivers for diversity receiving purposes spacing them at around 180 meters apart. He summarized his experiences in the March issue of Radio News Magazine in 1936. as "If the broadcast listeners had not wanted their receivers back, we would have kept on using diversity reception."

However, James Lamb, Technical Editor for QST, and engineer James McLaughlin decided that diversity was worth a try and began their research into some kind of practical amateur receiver that would incorporate diversity. [2]

3.1. The XE1G receiver

James Lamb and James McLaughlin had been separately experimenting with diversity reception as early as 1931. In the spring of 1935 they decided to have an informal meeting to discuss each others' thoughts on what technical advances might be used to create a practical amateur diversity receiver. A third person, a well-known amateur operator Dr. James M. B. Hard, XE1G from Cuernavaca, Morelos, Mexico, was ready to finance the construction of a dual-diversity receiver of Lamb's and McLaughlin's design. Both Lamb and McLaughlin thought that the tuning of commercial diversity receivers was too cumbersome because in an amateur station, the ability to tune through each amateur band easily and switch from band to band quickly was an obvious necessity. The XE1G receiver used a single Local Oscillator between the two receiver front ends to provide "single dial" tuning. Other circuits incorporated in the XE1G receiver were chain-driven with a tuning coverage from 1.7-30 MHz in four tuning ranges. [2] The completed receiver was delivered to Dr. Hard in 1936. [8] (Figure 3.1.)

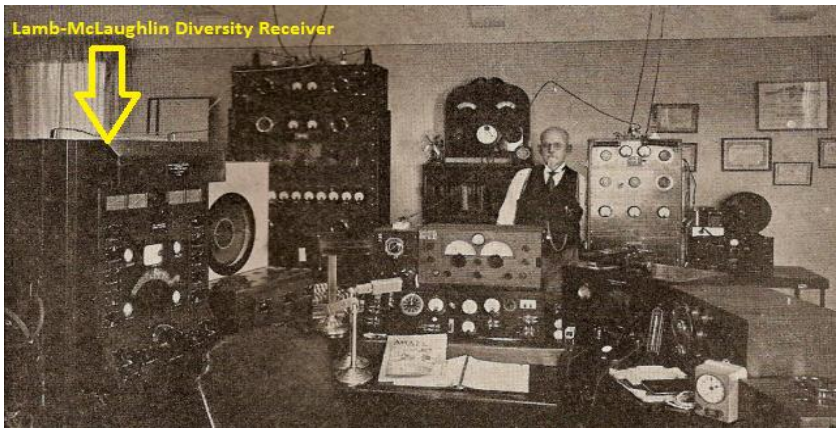

Figure 3.1. Dr. Hard and his Lamb-McLaughlin diversity receiver (1937)
Source: http://www.radioblvd.com/DiversityDD1.html (23/02/13)

Dr. Hard mainly operated on 20 meters with two antennas spaced at 15 meters, just sufficient to provide usable diversity action. With some mechanical improvements and technical development in IF amplifier the frequency range of the new prototype was extended to 540kHz - 36MHz and Dr. Hard's XE1G receiver had logged in 5000 hours of reliable operation.

It is also necessary to mention that there were some other attempts to use not so specially made receivers or even identical receivers for diversity. In the September 1939 issue of QST, S. Gordon Taylor described a diversity receiving system using Hallicrafters SX-17 and a Skyrider 5-10 receivers associated with a horizontal 10 meter dipol and one half of a vertical 5 meter beam. [9]

A slightly different approach to diversity reception was suggested by Forrest A. Bartlett in the same issue of QST. He feeded two separate preamplifers with two antenna signals paralelly connected their outputs to a single receiver. Switching the input of the conventional receiver between the signals, he produced a receiver output proporcional to the strongest signal present in either antenna at any instant of time. As a side effect, the structure implied a modulation content in the output with its frequency equal to switching frequency or its double, depending on the ratio of the receiver inputs. [9]

3.2. DD-1 prototype

Shortly after the QST article about the XE1G receiver was published, Hallicrafters became interested in building a dual diversity receiver for the amateur market. Working directly with James McLaughlin, Karl W. Miles, Hallicrafters' chief engineer was to build a dual diversity receiver. The first prototype of DD-1 underwent several technical modifications and was finally set in much smaller cabinet. (Figure 3.2.)

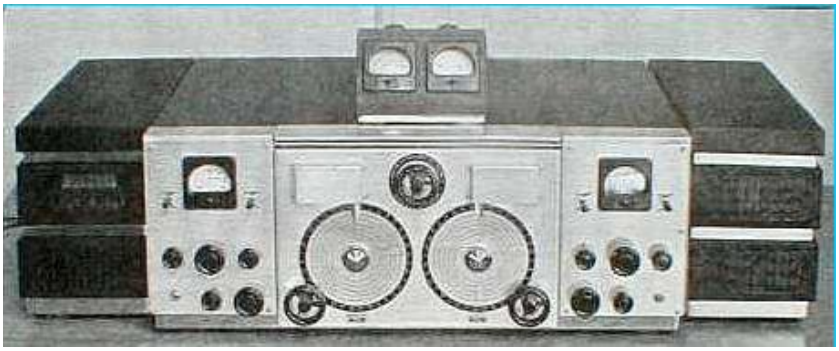

Figure 3.2. DD-1 diversity receiver prototype (1937)
Source: http://www.radioblvd.com/DiversityDD1.html (23/02/13)

As further improvements were implemented the later prototype and the production DD-1 are very different from the original Dr. Hard's one. Frequency coverage was also changed from the early prototype with the new range being 540kHz-36MHz in six bands. Besides few exterior changes in an arrangement of a front panel, as a main difference the production DD-1 used two IF amplifiers instead of three. [10]

3.3. The production "Skyrider Diversity" DD-1 receiver

Following Hallicrafters' tradition of naming receivers, the DD-1 was designated as the "Skyrider Diversity". Though radio broadcasting sector had a very wide segment in printed materials, the DD-1 production prototype was given the largest advertising campaign up to that time. [2], [11] Hallicrafters began advertising the Dual Diversity DD-1 in June 1938. and the DD-1 was only advertised till January 1939. [12] During these 6 months advertisements could be found everywhere. Despite a huge campaign it was widely supposed that the Skyrider Diversity was not going to be a major seller. The base price for the receiver was 300

USD, with the additional extras it could reach the amount of 500 USD which was almost a price of a new Chevrolet Coupe in 1938. As the price was rather high, Hallicrafters probably estimated that somewhere around 200 receivers would fill all of the orders besides all of the publicity donations that might be needed. But based on the results of quests carried out recently by serial number collector enthusiasts, only the production of about 100 to 125 DD-1 receivers in two production runs (approximately 100 units and later approximately 25 units) can be proven. It is also verifiable that the most majority of the receivers has been restored and renewed and are still available possessed by receiver collectors. (Figure 3.3.)

Figure 3.3. ”Skyrider Diversity” DD-1 production receiver prototype (1939)
Source: http://www.radiomuseum.org/r/hallicraft_skyrider_diversity_dd_1_d_1.html (23/02/13)

The major benefit to Hallicrafters was to their reputation as they had proven that they were capable of successfully engineering and building a complex, dual-diversity receiver for the market.

After World War II, there is hardly any mention of diversity in any ham magazines. The commercial stations and the military had always been and were to remain the primary users of diversity reception. As technology progressed into satellite communications by the late 1970s and other more reliable forms of communication came into use, the need for large, expensive diversity receiving installations all but vanished. Most of the equipment has been scraped or sold into surplus. [2]

During the second half of 20th century, radiocommunications technology underwent a lots of new improvements which finally manifestated in a dual or stereo receiving techniques.

5. SUMMARY

The first radiocommunications engineers being first to be faced with the fact of multi-path propagation and fading phenomena started their experimental analisys and understanding the behaviour experienced as early of 1920s. Based on Harold. Henry Beverage’s and his associate, H. O. Peterson’s first steps, the basics diversity reception techniques were deployed. In this article the early receiver prototypes have been introduced along with the first series producted DD-1 Skyrider receiver. Due to space limitation only the early milestones of history of diversity reception were presented in this paper. The diversity achievements of modern era and the way to the stereo reception technology being used recently, should be a subject of futher work.

References

[1] Pioneering in Electronics. The David Sarnoff Library http://www.davidsarnoff.org/kil-chapter01.html – (2013.02.23.)

[2] H. Rogers: Restoration of the Skyrider Diversity DD-1 Concole Receiver. Western Historic Radio Museum. http://www.radioblvd.com/DiversityDD1.html – (2013.02.23.)

[3] Oral-History: Harold H. Beverage and H. O. Peterson. http://www.ieeeghn.org/wiki/index.php/Oral-History:Harold_H._Beverage_and_H._O._PetersonD1.html – (2013.02.23.)

[4] Oral-History:Harold H. Beverage and H. O. Peterson. http://www.ieeeghn.org/wiki/index.php/Oral-History:Harold_H._Beverage_and_H._O._Peterson#Space_and_Polarization_Diversity_System – (2013.02.23.)

[5] Harol Henry Beverage, Explorer of the Wavelengths. Radio's 100 Men of Science,1944 ISBN 0-8369-1916-5 http://www.oldradio.com/archives/people/Harold_Beverage – (2013.02.23.)

[6] http://ok1ike.c-a-v.com/soubory/beverage.htm – (2013.02.23.)

[7] Pentti Stenman: The Muscle Radio: R-390A/URR. http://www.penan.net/dx/r-390a.htm (2013.02.23.)

[8] Diversity Reception and the Hallicrafters DD-1 – Part III. Carson Currents,,April/May 2003.12-13 http://www.cvrc.net/members/newsletters/AprMay03.pdf – (2013.02.23.)

[9] John J. Nagle K4KJ: Diversity Reception: An Answer to High Frequency Signal Fading. Ham Radio Magazine, September (1979), 48-55 http://www.epanorama.net/sff/Radio/Receivers/Diversity%20Reception.pdf – (2013.02.23.)

[10] Radiomuseum online. http://www.radiomuseum.org/m/hallicraft_usa_en_1.html – (2013.02.23.)

[11] Broadcasting History. http://www.americanradiohistory.com/Broadcasting_Individual_Issues_Guide.htm (2013.02.23.)

[12] Classic Pre-WWII Ham Gear 1928–1941. Radio Boulevard: Western Historic Radio Museum. http://www.radioblvd.com/Pre-WWII%20Ham%20Gear.htm – (2013.02.23.)