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Preface

Dear friends of COHIRADIA,

More than a year and a half has passed since the COHIRADIA landing page was set up and a lot has happened.

Until December 2022, the active 'team' consisted of relatively few interested people, of whom RMorg members Walter Barteczek and Stan Roberts are especially noteworthy, who not only provided essential ideas on many technical issues but also contributed quite a few interesting shots. I was also very pleased with the use of the RFCorder on the STEMLAB by Gerald Gauert at the Staßfurt Radio and Television Museum. Since quite a few AM stations in Europe were finally switched off in the last months (RAI Italia and Absolute Radio on MW, RTL Beidweiler and RTE Ireland on LW ...), we had our hands full with recordings to capture the last hours of transmissions of these stations together with all other frequencies of whole MW and LW bands for posterity. In response to a few calls for help on mediumwave.info from Ydun Ritz, Gianni Müller (Lucerne, Switzerland) joined the COHIRADIA 'family' in January 2023.

Gianni Müller has contributed several recordings made with PERSEUS back to 2015, all of which are of very good quality and document an even much greater station richness than we now have on MW and LW. His LW recording from 2019 with the stations Europe 1 and RMC Info, which were switched off shortly afterwards, is a real rarity.

At this point I would like to express my gratitude to all mentioned colleagues, because due to their very careful and time-consuming cooperation the archive of COHIRADIA has meanwhile reached a respectable size with typically very good data quality.

The effort is not to be underestimated, since the recordings must first be created with high-quality equipment, which requires certain planning in advance. Afterwards, all data must be resampled to a uniform file format that can also be played back by the RFCorder on analog radios. Particularly complex is the creation of the metadata, i.e. the frequency lists including information on transmitter site and reception strength, which makes it possible to identify the individual stations even later. Here the standard was set by W. Barteczek, whose template essentially forms the basis for the current documentation.

Special thanks are due to RMorg system administrator Ueli Kurmann, who built the entire IT infrastructure for COHIRADIA and is constantly working on the further development of the site with well-elaborated server programs. Thanks to his programs it is now possible to download the recordings either in the wav format necessary for many software-defined radios (SDRs) or in the dat format necessary for the RFCorder, the conversion is done automatically during the download. This means that a very powerful environment for archiving recordings is now available and it is getting better all the time.

Unfortunately, at the moment it still takes a few days from the actual recording to the release on the webpage, because each recording has to be checked by me and if necessary cut and resampled to a specific target frequency band. After that the annotation is done by the creators of the recordings, thank you very much for the effort.

The database will continue to grow, with many recordings since 2021 still pending, which have not yet been processed by me.

The highlight of the collection is the 'New Year's Eve/New Year's Day 2022/23' project, which consists of a whole package of simultaneous recordings of the MW and LW bands at 3 different locations in Europe and one location in the USA, made by Walter Barteczek, Gianni Müller, Stan Roberts and myself. The three European recordings include the shutdown of the two Slovak stations on 702 and 1098 kHz, and the shutdown of RTL on LW (234 kHz) the following day. This truly international project is unique because different transmitters are imaged differently depending on the location and directivity of the antennas used. We repeated this game again on January 19, 2023, this time on the occasion of the shutdown of Absolute Radio in England (1197, 1215, 1233, 1242, 1260 kHz). Also here a very nice diversity of the recordings can be seen, very interesting is the recording of Walter Barteczek, which is only 100 kHz wide, but has the best signal-to-noise ratio and contains all relevant frequencies.

It should also be mentioned that we have extended our recordings into the VLF range, which can already be seen on some of the recorded files. For example, we now always record when the machine transmitter SAQ Grimeton in Sweden makes its special broadcasts on 17.2 kHz. There is a first recording from 13.02.2023 on the occasion of the 50th anniversary of the UNESCO World Heritage Initiative, further recordings of this unique technical cultural monument will follow.

Of course, there were also quite a few technical developments in the context of COHIRADIA:

- Preparation of a version 1.2 of the RFcorder, so that wav-files can be played and recorded directly as well
- Integration of a semi-automatic tool called 'COHIWizard' for annotation (creation of metadata) of the recordings.
- Discussion on the use of alternative SDRs for recording and playback
- Details on file formats
- Recording practices: antennas, preamps, filters, etc.

The last point is important in that the first COHIRADIA contributions were still based on a clearly suboptimal technology of preamplifiers, the shortcomings of which were pointed out very clearly in a forum contribution by Walter Barteczek with his rich experience. As a result of this decidedly constructive criticism, the system in Graz was completely transformed within half a year, gaining at typically 20dB in signal-to-noise ratio. The still available first videos and descriptions in the RMorg are therefore to be taken up with caution regarding preamplifier and antenna and are to be revised in the future. More about this in the chapters 3.2 and 3.3.

The active COHIRADIA family is definitely still very small, and we hope of course to attract so much attention in the next years, that as many collectors and radio enthusiasts as possible, possibly also further museums will start to use COHIRADIA and its meanwhile quite respectable data treasure.

Hermann Scharfetter

Content

1 IDEA AND ORGANIZATION OF COHIRADIA:

1.1 BASIC IDEA:

COHIRADIA's central motto is summarized on the website's landing page:

> *Imagine being able to tune through and listen to all the stations in the medium wave band on your historic radio receiver at any time on a day in 2006, as if all the stations included were broadcasting right now. Obviously, the playback should not be based on an artificial montage, but on that authentic historical recording. This probably corresponds to the wish of many collectors, whose attractive and valuable devices will otherwise remain increasingly 'mute' due to the rapidly progressing final shutdown of AM transmitters. The COHIRADIA project fulfils this wish entirely!*

The basis for the realization of this idea is the fact that it is possible to store on data carriers not only single audio recordings but, if sufficient storage space is available, theoretically any broadband signals. As Jakob Roschy previously suggested on 16 Sep 05 in a forum contribution, one can store whole high frequency bands such as on medium wave between 500 and 1700 kHz by means of video recorders on video tapes and play them back afterwards. If you reconnect the antenna input of an old radio to the video output, you can tune to and listen to the signals as if the stations were active at the moment of playback. This makes it possible to play back complete radio tapes on almost any historical device, even if it dates from 1924.

The achievable signal-to-noise ratio on video equipment is quite modest, nevertheless H. Scharfetter made quite a few recordings of this kind starting in 2006. As he became aware only a year ago, this technique has been used for the USA database https://spectrumarchive.org/ since 1986. But of course today it is much cheaper to record and store the data digitally. This makes it possible to achieve an excellent dynamic range, and digital post-processing is of course also very convenient. Therefore, COHIRADIA was born only after the first videotapes were digitized and available on hard disk.

At the beginning, H.Scharfetter used a small, but very powerful, single board computer with FPGA~~,~~ called STEMLAB125-14 from Red Pitaya, for the digitization, as well as for the direct recording and playback of the AM spectra. This device has a very good resolution of 14 bits and sufficiently high sampling rates to accomplish all the above. Unfortunately, there was no convenient software, so H. Scharfetter was forced to write a Python-based software application called 'RFCorder', which can be used by anyone on a Windows PC. Thanks are due here to Pavel Demin from Red Pitaya, who provided some code snippets for the interface to STEMLAB.

At that time there was unfortunately no experience with other potentially usable so-called software-defined radios (SDR). Communication with S. Roberts led to first experiences with the RSP1A from SDRPlay (for more detailed information see section 3.3.1) and the software packages SDRUno as well as SDR# (for more detailed information see section 5.4). The RSP1A as well as its 'bigger brother' the RSPDx allow at least the recording of AM bands over very wide frequency ranges and the software is much more convenient and powerful than the 'RFCorder'. The data quality is excellent and the devices are extremely well suited for mobile use due to their small size and low power requirements. Unfortunately, you can't playback with the RSP1a, and many alternative products don't offer this feature either. Playback is possible with the AdalmPluto from Analog Devices, for example, but one needs a downconverter for the AM bands because the device can only be used from 70 MHz. For more details see chapter 3.2 and 3.3. For this reason the STEMLAB125-14 and possibly also its 'little brother', the STEMLAB 125-10 remains a very good and still reasonably inexpensive hardware for signal playback.

1.2 Current Team

Currently, 4 members of the Radio Museum actively contribute to COHIRADIA and thus form the core team:

Walter Barteczek, Neunkirchen-Seelscheid, Germany (DK8KV)

Gianni Müller, Lucerne, Switzerland (HB3XDC)

Stan Roberts, Los Gatos, California (AB6SR)

Hermann Scharfetter, Graz, Austria (OE6TWF)

By 'active' is meant that

- high-quality wideband recordings with SDRs are made and made available at regular intervals, especially when special events occur on the AM bands (e.g. transmitter shutdowns, special broadcasts, special phenomena...),
- forum posts are written on given occasions,
- to collaborate on the documentation of the recorded data sets,
- information about possible improvements of the hardware and about upcoming events is exchanged continuously.

In addition, there are some members who post interesting forum contributions again and again and thus also act as idea generators for the further development of the archive.

1.3 Other Archives

In the course of the expansion of COHIRADIA, internet searches from August 2022 onwards revealed three very interesting websites where amateurs have already published entire archives of SDR-wav files with recordings from MW and LW bands for free download, preferably in wav format:

(1) http://www.donmooredxer.com/ → My DX Travel Logs

Here many Latin American recordings can be found as well as a few LW recordings on which European stations also appear.

(2) http://pira.fmlist.org/perseus/

This is a European archive with rather short sequences from 2009. The collection was built by Günter Lorenz, who also runs https://www.mwlist.org.

(3) https://spectrumarchive.org/

This archive contains partly digitized recordings of video recordings back to 1986 (!). This corresponds to the technology used by H. Scharfetter for recordings between 2006 and 2009. They sound very similar in quality, with the characteristic rattle of the video head switching interference. Unfortunately, this archive does not include recordings from Europe.

2 ORGANIZATION OF THE ARCHIVE

2.1 CRITERIA FOR GOOD RECORDINGS

Naturally, as an enthusiast, one always records much more data than ends up in an archive for reasons of space. Therefore, the actual work usually consists not so much in the recording itself as in the post-processing. The 'valuable' data sets must first be listened to on several frequencies in order to select the segments that are worth archiving. In doing so, the signal quality has to be checked and, if necessary, simple corrections have to be made (e.g. amplitude boosting, if the dynamic range of the STEMLAB has not been used properly). In some cases, even certain sections of the frequency band must be cut out of recordings that are too broadband and/or resampling may have to be performed. Finally, there is the task of documenting the data sets, i.e., generating informative metadata that informs the users of the recordings about important contents and properties of the recordings. COHIRADIA does not yet have a very mature set of rules regarding these steps, so this chapter will formulate some thoughts on them.

2.1.1 Data quality

As is well known, the AM bands do not offer HiFi quality. Noise, crackling and pops due to static interference or ignition sources are simply part of short, medium and long wave listening. The threshold for recording stations for the archive should therefore not be set too high in terms of audio quality, otherwise it would not be a realistic representation of how the MW and LW bands used to sound. The true sound of most AM stations never had living room quality, unless one listened only to local ('local stations') or extremely powerful more distant stations.

Nevertheless, one should of course try to achieve the best possible quality for the recording location. Therefore, an attempt should be made in this document to write down some practical hints and rules.

A helpful indicator for the evaluation of the RF signal is the signal-to-noise ratio (SNR) of the transmitters of interest in a spectrum. The higher a useful signal rises above the noise background, the better the reproduction and speech intelligibility or music fidelity. The question is how to define the useful signal. In the context of COHIRADIA, the amplitude of the carrier has been used so far because it is very easy to determine. To be fair, it must be stated that the useful signal is actually contained in the sidebands, and therefore, with the same carrier amplitude, also depends on details of the modulation (modulation depth, spectral shaping of the sidebands, etc.).

A stricter definition in this respect can be found e.g. under [1]. However, in order to use it, e.g. the filter bandwidth of the IF filter must also be taken into account, and so the SNR displayed by certain software products (e.g. SDRUno) depends on the bandwidth selected in each case. For example, SDRUno typically displays 10 - 20 dB less than the distance between the carrier and the noise background. To avoid any resulting complications, the latter will continue to be used for COHIRADIA since it is unambiguous and simple.

For AM transmitters it is typical that below 30dB SNR the program usually already sounds very modest. On the other hand, on MW, for example, it is relatively typical that only a few stations rise above 40dB, and most stations farther from the antenna do not have a particularly high SNR. As a rule of thumb, most stations of interest for recording should not be less than 35dB (COHIRADIA definition). As a rule of thumb, most of the stations of interest for recording should not have less than 35dB (COHIRADIA definition). If this is not the case, archiving should only be done if there are specific reasons for doing so such as:

- extremely rare event worthy of preservation
- particularly conspicuous reception of stations which are normally not receivable at the recording location (e.g. very special, historically remarkable situation in the propagation conditions)
- particularly old recordings, e.g. before 2010 or similar.

Basically, two factors determine the resulting SNR:

- Transmitter signals and interference and noise background of the electromagnetic spectrum prevailing at the antenna.
- Noise and nonlinear distortion of the recording device

It makes sense that the limiting factor for the signal quality should not be the recording device. Currently, all recordings are made digitally via suitable SDRs. Therefore, for good recording quality, there are minimum requirements for the combination of sampling rate and digital resolution (bit depth of the ADCs). Lower bit depths can be compensated with oversampling if necessary. However, the (analog) preselection, the properties of the preamplifier and the antenna with regard to noise and intermodulation as well as the directional characteristic of the antenna are also very decisive. AGC should be de-activated, if this is offered by the software of the SDR.

The aspects mentioned can probably be summarized well in the term 'dynamic range'. Concerning this term one finds in [4]:

"...A good receiver needs a dynamic range of about 100dB....

...The number 100dB for phase noise limited dynamic range refers to "SSB bandwidth" which means that the noise floor of a good receiver has to be below -132dBc/Hz (3dB S/N loss, 3kHz bandwidth)."...

For the definitions see appendix 7.2.

Now the question is what exactly is meant by 'dynamic range'. In a digital system, the maximum usable dynamic range is the one between the digitization noise and the maximum processable signal amplitude. The best possible (theoretical) value is then the signal-to-noise ratio (SNR) of the digitizer. The standard formula for the maximum SNR of a quantizer is [9] for full scale with a sinusoidal signal and assumption of a uniformly distributed quantization error at n bit resolution:

$$SNR_Q = 6.02n + 1.76dB$$

If one wants to meet 100 dB, one needs 17 bit resolution. However, this can also be achieved with a digitizer of lower resolution by 'oversampling'. For example, if the MW band should be sampled with 1.25 MHz bandwidth, the effective sampling rate must be 1.25MS/s for the complex IQ protocol. Sampling at 125MS/s, i.e. with 100-fold oversampling, increases the SNR by a factor of 10 (square root of 100), i.e. 20 dB, which means a gain of slightly more than 3 bits (factor 8 would be exactly 3 bits). A 12-bit digitizer can therefore effectively have 15 bits of dynamic range.

For example, this results in about 14*6 + 1.7 = 85.7dB for the RSP1A up to 6MS/s IF sampling rate (see data sheet [6]) which is often used for COHIRADIA. Downsampling to 1.25 MS/s (typical for MW) results in a gain of about 6.8dB, i.e. about 92.5 dB. H. Scharfetter obtained quite exactly this value with actual measurements. For conversion to the noise floor in dBc/Hz, one must multiply with the bandwidth, so the value 10*log10(6*106) = 67dB must be added to 85.7. Theoretically this results in -152.7 dBc/Hz.

For the STEMLAB125-14 these calculations yield: 14 bit at 125MS/s correspond to 85.7 dB as with the RSP1A. Decimation to 1.25MHz (factor 100) results in 20dB SNR gain by oversampling, i.e. a bit more than 3 bit. This gives a theoretical dynamic range of 105.7 dB at 1.25 MHz. Converted to noise floor this results in the excellent theoretical value of -166 dBc/Hz. However, after a decimation of 14 , according to the hardware documentation [5] the data are internally handled via a bus with a width of only 24 bits. Therefore, theoretically only 145.7 dB signal range can be achieved. In any case, very good values result for this SDR as well and one can assume that the limitations are caused more by the preamplifier chain than by the digitizer itself. In general, one can assume that at currently common downsampling rates, typically 14 bit resolution of the input-side analog-to-digital converter (ADC) is a very good standard for COHIRADIA.

In practice, however, the 'usefully' achievable values are lower, since noise and nonlinearities of the preamplifiers cause signal degradation (see later section3.3.2). Nonlinearities cause intermodulations which lead to undesired crosstalk from strong transmitters to other frequencies. About intermodulation immunity: Normally the measured IP3 (Interception Point of 3rd order) in context with the phase noise measure gives a sufficient indication about the quality of a receiver. However, the IP is not easy to measure. It indicates the intersection point of the intermodulation products with the wanted signal, and is thus a theoretical (i.e. fictitious) value. The rise of the 3rd order intermodulation product has three times the slope compared to the wanted signals, therefore there is an intersection point beyond the 1dB compression point, i.e. outside the typical operating range. Values between +20...+30dBm are considered good.

In the data sheets of the SDR systems used in COHIRADIA, one can find relatively detailed information about the dynamic range. Mostly they do not refer to the theoretical value, but to the actually achievable value under compliance with a specified IP3.

In order to achieve a good standard, the chapter 'Hardware' deals with the most important elements to meet the above requirements as far as possible. It must be admitted in this context that the recordings made with video recorders up to 2009 (see section 4) are nowhere near the values indicated, and can therefore only be considered 'historical' as far as the content is concerned.

2.1.2 Selection of contents

The second important question is: what content is worth recording? To have a good cross-section, one should image all AM bands a few times a year for at least one hour without considering special content under good recording conditions. The actual number depends somewhat on the regions and the expected transmitted content. In Europe, there are still a few MW and LW stations broadcasting various high-quality information (e.g., BBC), while in the U.S. most MW radio stations broadcast only news, talk radio, religious programs, or programs in minority languages. In addition, most stations broadcast frequent commercial segments, so program material tends to be superficial and repetitive. The result is that very little content is available except during important events of national/international interest. Therefore, depending on the region, 1 - 3 recordings of all major bands per year would largely suffice. Preference should be given to the winter months, as conditions for long-distance reception are then much better than in summer, and there are also fewer thunderstorm crashes.

On shortwave, the selection is a much bigger challenge, because the stations change a lot during the day and it is difficult to decide what is 'representative'. Here, the topic of 'long distance reception' is certainly interesting, such as whether one can receive e.g. Havana, Radio Marti or R. New Zealand in Central Europe or e.g. Radio Austria in New Zealand.

In addition to regular archiving, selective recordings should be made in special instances, e.g.:

- Switching off particularly well-known and traditional transmitters

- Re-commissioning of AM stations (currently rather rare, but does happen)

- Transmission of historically interesting events on one or better several transmitters (example: coronation of Charles III on BBC4, LW)

- AM transmitters in use for information and propaganda purposes in the context of historically significant exceptional events. Example: Ukraine war (reactivation of Ukrainian MW stations, their partial destruction, Russian propaganda at the same time e.g. on Grigoriopol...).

2.2 Documentation and Annotation

Each data set is only worth as much as it is documented. Here, W. Barteczek certainly set an excellent standard when he meticulously annotated every conspicuous transmitter peak in his recordings right from the start. Based on this practice, a standard metadata set was defined in cooperation with Ueli Kurmann, which has to be generated for each recording. The metadata contains some information about the receiving station (location, operator, receiving equipment, recording time...) and then for each received station the frequency, SNR (or S-level), station/program and station location if known. This information was first generated manually in the form of so-called yaml-files, which then serve as the data basis for the information on the landing page. Ideally, the person doing the recording also fills in the annotations. Since this can be quite time-consuming (e.g. for MW theoretically there are more than 120 broadcast frequencies), a software tool ('COHIWizard') was written by H. Scharfetter for internal use, which facilitates this procedure by generating suggestions based on known station lists (e.g. from mwlist.org). This program is still in an early testing phase, but will be updated and omproved at regular intervals.

At this point, many thanks to all who carefully provide the metadata.

2.3 BISHERIGER BESTAND

The existing archive can be accessed completely from the COHIRADIA landing page and all recordings are listed in a clickable list with hopefully well understandable titles. Currently there are about 27 hours of broadcast band playtime stored there (each band contains x stations, so the total playtime of audio content is many times larger).

As important examples the following data sets may be mentioned:

- 30/31-12-2006 (Graz): Analog recording of the MW band, here you can still find quite a few German language radio stations like Deutschlandfunk, Bayern 1, MDR, Radio1476 (Vienna Bisamberg), weak signals from Beromünster, furthermore 'Option Musique' (Sottens), France Info and AFN, which stopped their service during the following years.
- 01-01-2009 (Graz): Analog recording of the 49m band (shortwave) on New Year's Day with station announcements at 11:00 CET. Some now switched off stations like R. Netherlands, Deutschlandfunk, R. Austria International, R. Vatican
- 20-07-2015 (Luzern): Central European MW around midnight (CET), many European stations, also still from D and F; some national anthems played at midnight (e.g. RAI, DLF).
- 31.12.2019 (Hildisrieden): LW recording, includes Europe 1 (DE) and RMC Info (F), pronounced Luxembourg Effect on 162 kHz and 183 kHz. This is certainly a unique file as such LW recordings are extremely rare.
- 27-04-2022 (Los Gatos): MW recording in California, good and densely populated spectrum.
- 18-07-2022 (Lossburg): LW, strong Luxembourg Effect on 162kHz/198kHz; overlay of the transmitters of Tipaza and Dublin @ 252 kHz with a shearing effect; with increasing twilight an exceptionally strong Luxembourg Effect develops: modulation of Beidweiler (234kHz) on 162kHz Allouis and 198kHz Droitwich
- 10-08-2022: Mobile recording on a ferry in the Adriatic Sea, 1 month before shutdown of all RAI MW transmitters
- 10-09-2022: Shutdown of all RAI MW transmitters on 657, 900, 936, 999, 1062, 1107, 1116, 1431, 1449 ,1575 kHz. End with the Italian anthem and 24:00(I) time signal (22:00 UTC).
- 14-04-2023: The last hour of RTE (Ireland) on 252 kHz (LW), recorded at 2 locations: Luzern, Neunkirchen-Seelscheid.
- 18-05-2023: Historical broadcast for the 100th anniversary of Czech Radio on 1233 kHz

Remarkable highlights are certainly the datasets where special events were recorded simultaneously at 3 - 4 different locations, in particular:

- 31-12-2022 and 01-01-2022: 'New Year's memories 22/23: simultaneous recording of LW and MW at 4 locations (Graz, Los Gatos, Luzern, Neunkirchen- Seelscheid) with the following events:

- Last hours of the Slovak stations on 702 and 1098 kHz on 31.12.2022
- Last hours of RTL (234 kHz) on LW on 01-01-2023 (Europe only), partly with strong Luxembourg effects, 189 and 207kHz from Iceland partly with speech intelligibility (Luzern, Neunkirchen-Seelscheid.
- 19-01-2023: Last hours of Absolute Radio, simultaneous recording of LW and MW at 3 locations (Graz, Luzern, Neunkirchen- Seelscheid).

In processing state and already partly available: MW recordings from New Zealand (July/August 2023), Sweden (August 2023) as well as an LW recording in the early morning on which RTL and Kalundborg still switch on in sequence.

Recordings are planned for known shutdown dates such as Kalundborg at the end of 2023, Gold London in Sept 2023 and BBC4 in mid-2024. MW and LW recordings are also planned for Sardinia (ITA) in September 2023.

2.4 VHF-Projects

In view of the increasing introduction of digital transmission in the FM bands (keyword DAB+), archiving contemporary analog FM bands is certainly interesting, but takes up incomparably more bandwidth and resulting storage space. Nevertheless, it is planned to provide space for this in COHIRADIA. In any case, recordings prior to FM shutdowns, such as those planned for Switzerland at the end of 2024, should be planned soon. However, many SDRs are not suitable for recording an entire FM band at once. First experiments with sub-bands of up to 5MHz width were carried out by H. Scharfetter on RSP1A and were quite positive, but still suboptimal.

G. Müller reports from HAM Radio 2023 that, according to Microtelecom, an entire band will theoretically be recordable with Perseus 22 announced for fall 2023. This would be of great advantage for COHIRADIA.

Also planned are experiments by H. Scharfetter with the ADALM Pluto from Analog Devices, which can be operated unofficially from 70 MHz with 12 bit resolution and up to 20MHz bandwidth.

A systematic archiving of VHF bands has not been started yet.

3 HARDWARE

3.1 GENERAL THOUGHTS

When selecting the hardware, the first thing to decide is whether the device is to be used only for playback of wideband signals on analog radios, or whether you also want to make your own recordings. For radio collectors and museum operators, pure playback is probably the method of choice, while enthusiasts interested in archiving (active COHIRADIA members) and radio amateurs also want to be able to record. Therefore, two separate sub-chapters for the respective use cases follow. Common to both is the use of a software defined radio (SDR), since the use of analog techniques (keyword video recorder) is probably out of the question for serious purposes nowadays. For pure playback, only a coupling element to the radio (usually a balun or unun) is added. If you want to record, you need a complete receiver chain with antenna, filters, preamplifiers and possibly further coupling elements. As far as SDR is concerned, there is a large number of different devices on the market and it is not easy to get a good overview. At the time of this report a very useful list was found on the pages

https://www.rtl-sdr.com/roundup-software-defined-radios/

and

https://www.rtl-sdr.com/about-rtl-sdr/

where a table with a quick comparison of the important key data and prices exists. All devices listed there communicate with established and mostly freely available, reasonably mature software products. The STEMLAB 125-14 from Red Pitaya, which was primarily used for COHIRADIA, is not listed there.

The lists contain a number of inexpensive SDRs, but only devices with 14 or 18 bit resolution in the first ADC are recommended; 12 bits must be considered as borderline.

The IQ data must be able to be stored with at least 16 bits/sample (better 24). Systems like 'HackRF' with only 8 bits are probably suitable for radio operation, but certainly not for COHIRADIA. In the following two chapters some of the offered products will be discussed in more detail. However, the authors make no claim to completeness or suitability, since the market for SDRs is very dynamic and not very clear.

3.2 PURE SIGNAL PLAYBACK (TX ONLY)

3.2.1 General setup:

The RF broadband signals are transmitted from the transmit output of the SDR to the antenna input of the radio by means of an isolating RF transformer. The basic wiring is shown in Fig. 3-1.

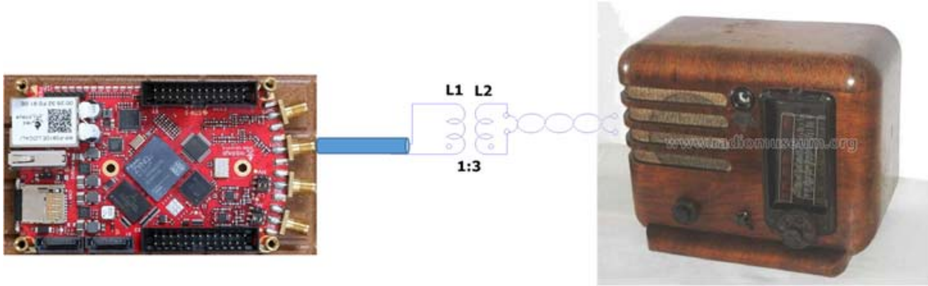


Fig. 3-1: Coupling oft he SDR (here STEMLAB125-14) wuth a radio receiver by means of an isolating RF transformer L1:L2 (Balun, Unun).

3.2.2 SDR:

The SDR must have a transmit output with good digital resolution (typically > 12bit). There are a few products, which are used in the amateur radio range. Two reasonably inexpensive systems have been tested by H. Scharfetter so far:

STEMLAB125-14 from Red Pitaya, which besides having a very good resolution of 14 bit, also has sufficiently high sampling rates (2x 125MS/s) for the necessary oversampling. Without a converter, the SDR can be used from DC to about 60MHz, so it is optimal for all classic AM bands including VLF, if that is desired. In the specifications of the STEMLAB 125-14 the dynamic range without oversampling is 80dB, which is still a good 100dB at 1.25MS/s for medium wave. The device costs less than 500€ and fits in any drawer due to its compact design. Disadvantages:

- There are no switchable preamplifiers and/or filters on board.
- There is no commercial software for recording and playing back the usual IQ files used for wideband recordings.

H. Scharfetter has therefore written his own software called 'RFCorder' under Python, which is open-source and freely available. For Windows there is an exe version which can be downloaded from RMORG.

In a quick (not very comprehensive) subjective listening test, interestingly the much cheaper STEMLAB125-10 (currently under 300€) also performed well when playing back AM recordings with seemingly quite acceptable dynamic range. It seems thus to be an acceptable economic alternative with usable playback quality. However, a quantitatively reliable analysis was not carried out to date and recordings were not made. Basically, from the requirements stated in previous sections it cannot be recommended for recordings due to the limited dynamic range (60dB without oversampling, 80dB at 1.25 MS/s).

ADALM Pluto from Analog Devices: This is the only reasonably inexpensive potential alternative to STEMLAB known to the authors. The device works officially from 325MHz, unofficially it can be operated from 70 MHz. So to play AM bands an additional downconverter is needed. The resolution is 12 bit and one can play up to 20 MHz wide bands. The present cost of 260€ is relatively low. For software GNURadio or SDRAngel can be used. H. Scharfetter has undertaken some preliminary tests with SDRAngel. After getting used to the somewhat unconventional software structure (requires the interconnection of 'building blocks') own AM recordings could be upconverted into the VHF band and played back there. Attempts to play back the signals on the original frequencies by means of downconverters are still pending, but this is probably relatively easy by means of a signal generator and a mixer.

In addition, the following product is probably suitable according to the description:

Blade-RF Micro xA4 (https://www.nuand.com/bladerf-2-0-micro/#blade-overview-wapper): usable from 47 MHz, so similar to ADALM Pluto not directly suitable for AM bands. However, there is a 'transverter' (up/down converter) (according to the list about 250$), which also allows lower frequencies. The bandwidth of 28 MHz is very good, and the resolution with 12 bits quite usable. If you limit the bandwidth to 1.75 MHz, you could probably effectively gain 2 bits. Base price 540$; total price incl. converter probably not below 800$. Support by several software platforms.

There are several other products, such as the USRP B200/B210 (Ettus), but these are priced out of the typical amateur budget. The USRP B200 is only usable from 70 MHz, so for MW only together with a downconverter. The costs for the pure board are 1270 €.

3.2.3 Coupling transformer (Balun):

The antenna input of many old tube receivers presents comparatively high AC voltages vs. ground due to relatively high parasitic capacitances. Connecting the grounding socket directly to the grounding conductor contact of a power outlet may even trip the Residual Current Device (RCD) or circuit breaker on some models. Therefore it is strongly discouraged to connect the output of the STEMLAB directly to the antenna input. Not only can the STEMLAB be damaged or destroyed, but it is also dangerous for persons handling it to touch the corresponding conductive parts.

The remedy is to use a high-frequency isolating transformer with a suitable transformation ratio from the 50Ω output of the STEMLAB to the radio. Usually an impedance transformation of 1:9 to 1:16 (turns ratio 1:3 or 1:4) works for typical tube devices, so that for the respective frequency range suitable baluns or ununs can be used.

Baluns or ununs used in the respective frequency range by ham radio amateurs are suitable, if primary and secondary side are completely galvanically separated (no common ground !). Alternatively, any experienced hobbyist can wind such a transformer as long as due safety isolation of the windings is considered. In the first COHIRADIA video tutorial a pot core transformer with a turns ratio of 1:4 and an inductance of 64µH : 1 mH (radio side) was used for LW and MW. Toroidal core transformers were successfully used by two other RM members:

(a) Toroidal core FT240/77, primary 10 turns, secondary 30 turns with a 0.5mm enamelled copper wire. This variant was tested by Franz Wolf with an amplitude modulated signal generator RF1 from HEATHKIT and a CD-Player on a LOEWE Opta-Kantate, the result was rated by him as very satisfactory.

(b) Gerald Gauert reports successful playback from STEMLAB via a Ferrite toroid, primary 65µH, secondary 1.3mH. However, he has recorded the signals on a *Staßfurter Mikrohet* built in 1928, which has a loop antenna. So the coupling is done from the transformer to a second loop antenna for inductive coupling. Therefore it is still unclear whether the transformer is optimal for this mode of operation.

As ferrites are generally suitable the materials 77 (LW,MW) and 43 (works also well for SW bands), the size does not have to be FT240 but smaller rings can be used quite well, since no large currents flow in the windings and saturation is not likely.

Gerald Gauert reported that with some old equipment the antenna contributes considerably to the resonator capacitance and therefore the mere coupling of the STEMLAB via a balun leads to undesired attenuation and frequency shifts of the tuning circuit. Significant signal interference can also be the result. H. Scharfetter found similar effects with an Atwaterkent 10 from 1924. In such cases it is recommended in the MW band to connect a 220pF capacitor and a resistor (470 – 2200Ω) in series between the balun output and the antenna input of the radio. This measure can usually solve the problem or at least significantly mitigate it.

In principle, a purely inductive coupling via a transmitting coil and a suitable driver stage and low power (compliance with the regulations for interference radiation!) to devices that have ferrite antennas or frame antennas is also conceivable. Tests for this have not yet been undertaken.

3.3 PURE RECORDING OR BOTH RECORDING AND PLAYBACK (RX AND TX)

If both playback and recording are desired, the same SDRs described in the chapter 'Pure signal playback (TX only)' are suitable. If one only wants to record (because analog playback is not needed), a number of other additional systems come into question.

In the context of COHIRADIA there is one aspect that requires special attention: Operators of classical radios and radio systems are typically used to having a selective element (resonant circuit, narrowband filter) very early in the signal chain, and often the antenna itself is already narrowband. For the wideband recordings required for COHIRADIA, the situation is completely different: the entire signal chain must be as wideband as the band to be recorded, i.e. more than 1 MHz for MW. This results in special requirements for the antenna, preamplifier and filter. Particularly critical is the risk of intermodulation artifacts, since strong interferers or local transmitters often cannot be easily filtered out. Some SDRs already have built-in switchable filters and preamplifiers, but this is not the case with the STEMLAB. Therefore, special space is given to these elements in this chapter.

3.3.1 SDRs for pure reception:

RSP1A and RSPdx (Airplay, https://www.sdrplay.com): These devices are actively used by several of the authors and they can be highly recommended. They are robust, small, light, mobile, and have very good performance data. Compared to the RSP1A, the RSPdx has a metal housing and is therefore somewhat more resistant to interference. It also has 3 switchable antenna inputs, which is sometimes handy. The noise figure is 2 dB worse than the RSP1A at low frequencies (nominally), but this is not noticeable due to the relatively strong atmospheric noise at LW and MW. Operation is very simple, everything works plug and play. The best software to use is SDRUno under Windows, but there are also third-party alternative software products. With a frequency range of 1kHz - 2GHz, an ADC resolution of 14 bits (up to 6 MHz bandwidth) and a recording bandwidth up to 10 MHz (but then much worse SNR) as well as built-in filters for the most important bands, an RSP1A offers a really good price-performance ratio for about 150€ currently. Alternatively (not tested by the authors), the almost twice as expensive RSPduo from the same company, which includes a double tuner, might be an option. The usable dynamic range is close to 100 dB, if the 'Gain' control is not turned up fully, because then the IP3 gets noticeably worse. Detailed information can be found in the data sheet [6] of the RSP1A.

Airspy Hf+ Discovery (airspy, https://airspy.com/) is a very solid device with excellent resolution and good noise data at a good price (between 170 and 230€). However, it unfortunately only has 768 kHz recording bandwidth, so it does not allow recording the entire MW band in one. The Airspy Hf+, the predecessor of the Discovery, was tested by G. Müller. It is theoretically very well suited for reception on the MW / LW band. In terms of reception quality, it is roughly comparable to the RSP1a, but it can handle strong signals a little better, so is less quickly slightly less likely to overload. Unfortunately the bandwidth is limited to 964KHz even with the latest firmware. So this is also a bit too narrow for the entire MW band.

The **Airspy R2** solves the bandwidth problem, but starts only at 24MHz and can therefore only be used together with the 'SpyVerter' for LW/MW/KW offered by the same company. At a total price below 250€ this combination is probably a good solution.

The software support is good for both products.

Perseus SDR (https://www.microtelecom.it):

The Italian company Microtelecom s.r.l of Nico Plaermo, IV3NWV, has already developed in 2007 a very powerful SDR receiver, which is still excellent for observing and recording a band spectrum up to 2000 kHz. According to the data sheet [5], the PERSEUS has a 14-bit analog-to-digital converter with 80 MS/s. Theoretically, this results in 85.76dB for the digitizer (as with STEMLAB 125-14) or 131 dB with a bandwidth reduction to 2.4 kHz (SSB). In the data sheet, taking into account the 1 dB compression point of the system, a blocking dynamic range of 117 dB is given for SSB, which is still excellent and corresponds to a real noise floor of -151 dBc/Hz. This is significantly better than required by [4].

To avoid overloads, there are 10 passband filters, a three-stage attenuator and a dynamic preamplifier with a 3rd order intercept point of +30dbm.

In recordings made by G. Müller in the MW and LW range, the PERSEUS clearly proved to be the most sensitive receiver with the best signal-to-noise ratio in direct comparison with an RSP1A and an Airspy HF+. The PERSEUS offers the best system compatibility with the included software (currently V5) on a Windows operating system. However, (experimental) Linux drivers are also available online. In addition to the receiver and control software, a server application is included that makes the receiver controllable via the Internet.

Note: The Perseus SDR draws about 750mA current, so for portable operation at least a laptop with USB 3.0 port is required, since USB 2.0 usually delivers only 500mA. In practice, G. Müller has made the best experiences when the receiver is powered directly via the PC, since the switching power supplies often lead to interference.

However, the excellent performance of the PERSEUS reported by G. Müller, even after more than 15 years, also has its price. The PERSEUS is significantly more expensive than the other receivers presented here. The SDR is available with the associated software, which also allows remote operation, from about 830 €.

Perseus 22: In autumn 2023 a completely revised version of the Perseus SDR will be released, which G. Müller has already seen presented at HAM Radio 2023 by means of a live demo at the ELAD booth. On the webpage of Microtelecom one can read:

> *««Perseus22 is a 4 channels, direct sampling receiver with a continuous frequency coverage from 10 KHz to 225 MHz and a typical image rejection larger than 70 dB.*
> *All channels are synchronously sampled by an high SNR, 14 bits A/D converter and processed by a software defined digital down converter, implemented on an FPGA, which outputs are routed to the host PC by a USB 3.0 controller, allowing wide-bandwidth IF applications.*
> *The frequency coverage is split-up in 2 groups of channels (two for VLF-HF frequency range, the others for VHF), each one capable of diversity, which can reduce noise in order of tens dB. All channels includes an analog RF frontend equipped with attenuators, preselection filters and amplifiers.*
> *The receiver enclosure is machined from solid aluminium and finished with a fine, non reflecting, black surface treatment.»*

What makes the receiver particularly interesting, among other things, is that up to 4 frequency ranges can be viewed / recorded simultaneously. The device also apparently has a "built-in QRM eliminator" that can separate interference signals from useful signals with an auxiliary antenna. Phase shifting is probably also used here, which is to be implemented automatically with software support. The software's algorithm should be able to help filter out a maximum of interfering signals from the useful signal or even null out an interference signal.

If the device is to be used mobile, the power consumption is an issue because of the battery life. Here, the RSP1A performs best with a power consumption of only 185 mA (see video at https://www.rtl-sdr.com/measuring-the-usb-power-consumption-of-various-software-defined-radios/). If it is desired to take the recording device in a backpack on a hike, the device also scores with its low weight and size.

In summary, it can be stated that all SDRs currently used for COHIRADIA show performance data that meet the requirements stated at the beginning.

3.3.2 Preamplifiers

In many cases, SDRs make the use of preamplifiers unnecessary because they have built-in LNAs. However, preamplifiers are necessary for short wideband antennas or under unfavorable receiving conditions and when using the STEMLAB 125-14 as an SDR.

3.3.2.1 Basics on preamplifiers: Gain, stability, noise, intermodulation immunity

Basically, what experienced radio amateurs have known for decades applies also to COHIRADIA. Concerning preamplifiers, please refer to the highly regarded article "Receiver input section with large dynamic range and very low intermodulation distortion" by Michael Martin in June 1975 [8]. The most important rules that follow from this article are:

- the selection means (bandpass, lowpass filters) between the antenna and the first active amplifier stage must introduce as little attenuation as possible
- the first stage should be set with only moderate current (about 10mA) if the right transistor is chosen, in order to keep the noise low. The next stage should then be coupled with the correct impedance and operate at a much higher current.
- Cascading identical amplifiers is not always practical and should be used very carefully, if at all. Ideally, each stage should be dimensioned differently and matched to each other.
- Intermodulation immunity: To avoid 'phantom stations' on unexpected frequencies in the spectra of recordings, intermodulation products are extremely undesirable. Therefore, when selecting amplifier circuits, high linearity over a wide dynamic range must be considered.

When using SDRs, the dynamic input range is an important issue. Good modern devices have built-in preamplifiers and filters. The STEMLAB125-14 from Red Pitaya, which was initially also used for recordings in COHIRADIA, is a bare-bones board, so that preamplification is necessary at low levels. The target level of 1Vpp for the optimal input level of the STEMLAB, is a real challenge depending on the antenna signal. To avoid oscillations due to unwanted feedback, each preamplifier stage must be individually shielded and the power supply carefully smoothed. More than 30dB straight amplification is not recommended; if necessary, one should be satisfied here with a lower utilization of the dynamic input range, since the digital resolution of the SDR is relatively high anyway.

Now, of course, every antenna situation is different. Decisive parameters are the local interference level, ground conductivity, effective antenna height, etc. In addition, the levels on medium wave fluctuate quite considerably from night to night and from night to day, and vary in the long term with the solar flux fluctuating in the 11 year sunspot cycle. Ionograms show that in summer (in contrast to winter) often only the lower E layer is reached by the radio waves.

The maximum dynamic range that can be expected from the STEMLAB with its 14-bit converters is 85.7 dB (without downsampling). That much signal range can hardly be expected at an antenna. W. Barteczek reports from his very good dipole antenna that normally it reaches no more than 60 dB. If he uses it on long wave, then the preamplifier gain must theoretically be about 35 dB. For nighttime medium wave he hardly needs more than 20dB gain.

At this point, the transistor 2N5109 from 1975 comes back into focus. It was developed because of the then emerging TV broadband cable technology, is still available today, but basically discontinued. Equipped with a cooling star, it can draw up to 400mA collector current.

The older 2N3866 can be used in a similar mode, but was originally used as a driver in the 2N3375/2N3632 VHF transmitter family.

Many modern components (including op-amp solutions) are probably handicapped by the fact that up to 120 channels on medium wave have to be processed at a similarly high level. Such a thing hardly ever occurs in other frequency ranges and requires high intermodulation stability. As a reminder: If the number of channels to be amplified is doubled, the possible modulation drops by 3dB of power.

3.3.2.2 Transistor based preamplifier using the example 2N5109

In the RCA data sheet December 1969 details can be found, e.g. how to bifilarly wind the 4:1 toroidal balun. The transistor is low noise and low intermodulation and was developed for US cable television.

Fig. 3-2 shows a basic amplifier circuit and Fig. 3-3 shows noise figure and gain from the RCA-datasheet.

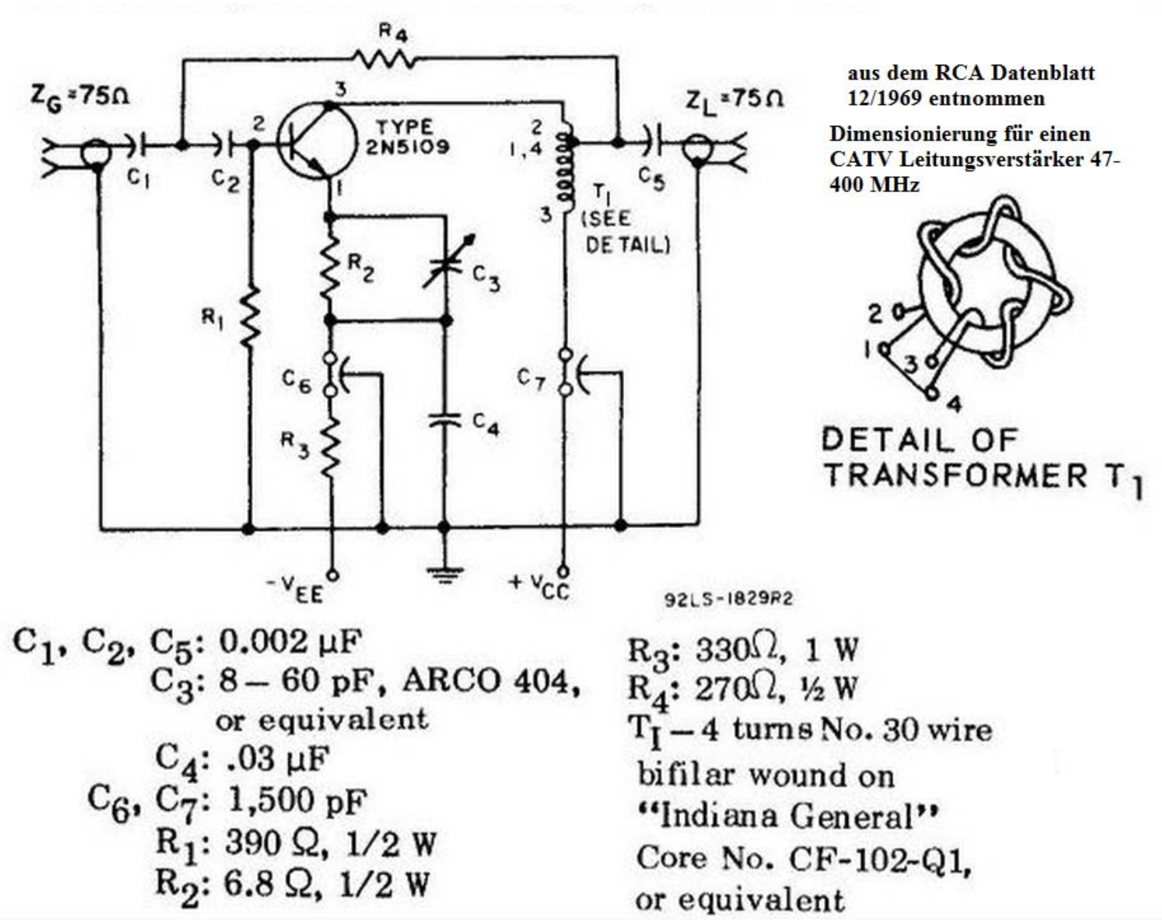


Fig. 3-2: Basic circuit of a preamplifier with the 2N5109

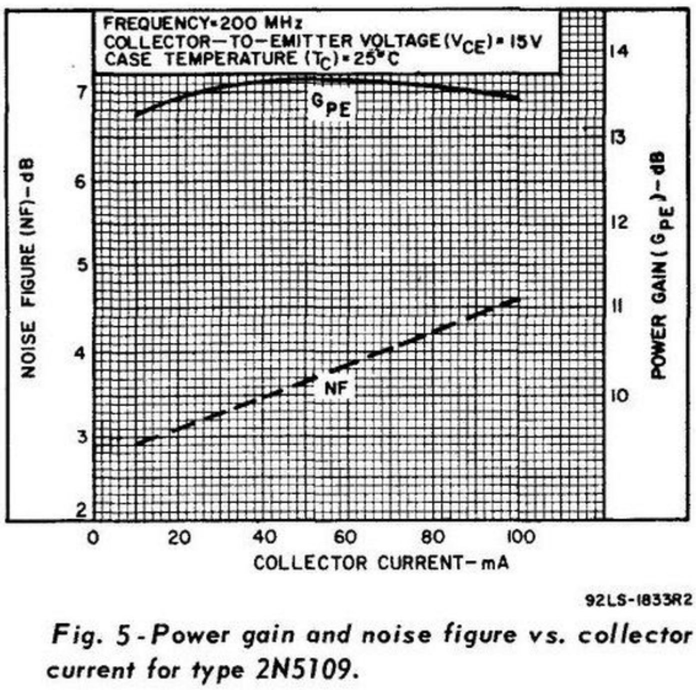


Fig. 3-3: Noise figure and gain of the 2N5109.

For the AM frequency ranges below 30 MHz, the following dimensioning in Fig. 3-4 has proven successful:

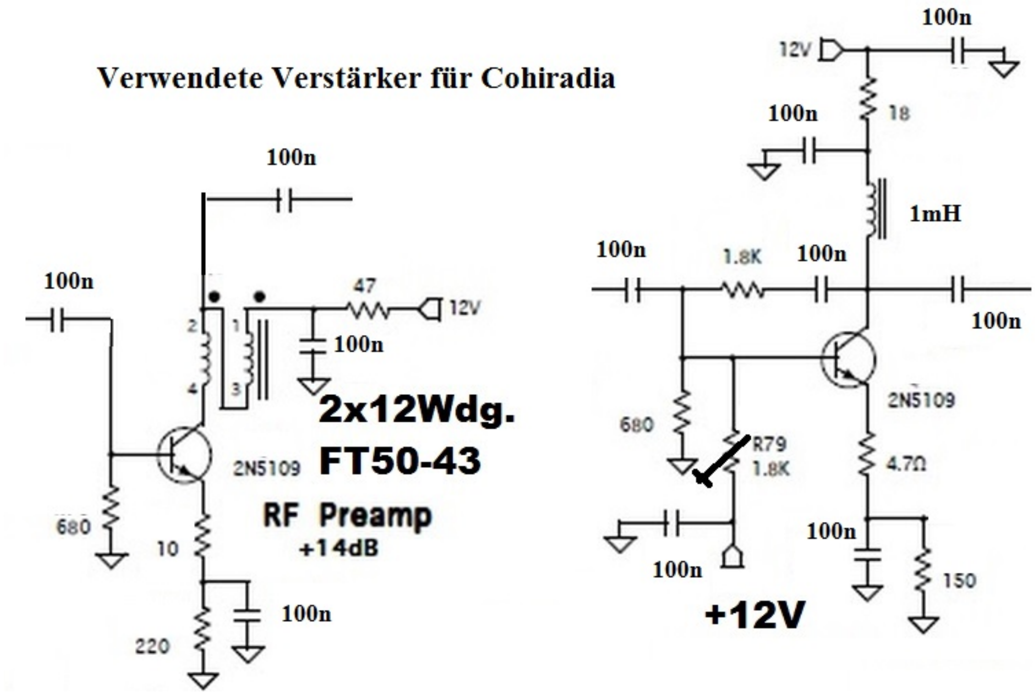
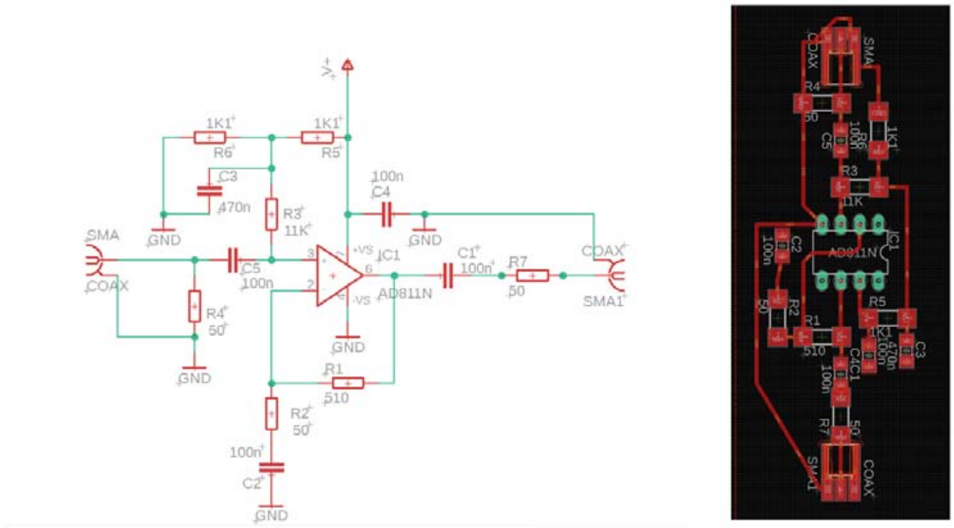


Fig. 3-4: two-stage preamplifier with 2N5109 for COHIRADIA.

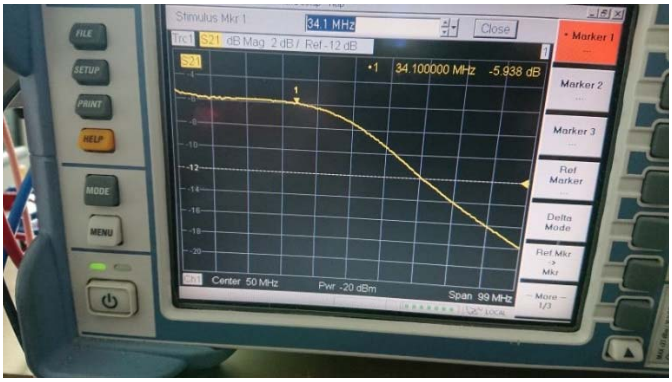
The collector current to be set should be about 10 mA in the first stage and 35 to 60 mA in the subsequent stage. This circuit largely corresponds to the one used in the Elecraft K2 transceiver (circuit diagrams can be downloaded from the company website [12]).

3.3.2.3 Preamplifiers based on operational amplifiers

In principle, low-noise operational amplifiers can also be used for broadband amplification, provided their transit frequency is high enough. In the first year of COHIRADIA, H. Scharfetter liked to use the AD811, which is a relatively broadband low noise video amplifier. Schematic and layout can be found in Fig. 3-5A. In Fig. 3-5B the gain frequency response is depicted, the cutoff frequency is about 45MHz (at 12V supply voltage). The gain in this case was about 14dB at a 50Ω system. The supply voltage can theoretically be up to 30V, but this is not recommended due to significantly higher power dissipation. This amplifier was also used in cascade by H. Scharfetter. With 2 stages in series and good individual shielding (tinplate housing and proper feedthrough capacitors for the supply) there were still no instabilities. With 3 stages with an interconnected attenuator between 2nd and 3rd stage there were occasional oscillations under unfavorable conditions (see high gain straight reception). More than 40 dB is not recommended.



A



B

Fig. 3-5:
A: Schematic and layout for preamplifier with AD811.
B: S21 measured with a Rohde&Schwarz ZVL3 and 20-dB attenuator at the amplifier input. The read off -5.9 dB hence correspond to an actual gain of 14.1 dB @50Ω

The noise figure of this amplifier is about 29dB at 50Ω, so not comparable to usual LNAs. However, if the input impedance is made high with high values of R4 (e.g. 100 kΩ or more) and the antenna can offer broadband 100Ω impedance, the noise figure could be brought down to <7dB. At 500Ω one still gets 14dB. In any case, good matching transformers are required. The article [13] served as a basis for the noise figure calculation.

In general, however, these noise figures are quite acceptable, since the atmospheric noise and local QRM exceeds the amplifier noise in the range of the LW/MW bands anyway.

Intermodulation immunity:

W. Barteczek performed two-tone tests on several amplifiers to evaluate the 2N5109 amplifiers in his setup in comparison with the AD811 used by H. Scharfetter: The measurements also served for determining the optimal current in the second 2N5109.

The IMD3 was used as the evaluation index, i.e. the lowering of the 3rd order intermodulation products, i.e. at 2x(f2-f1) and 2x(f1-f2). They arise at the same frequency spacing to the two carrier frequencies f1 and f2. Cross modulation, on the other hand, does not obey any direct mathematical relationship, although it also arises in context with a non-linear transmission characteristic. It mostly occurs in the region of the modulation limit near the 1dB compression point.

If one looks for an optimum for the spectrum analyzer HP8591E used by W. Barteczek with respect to level impact and pre-attenuation, then the IM measurement limit for intermodulation measurements is about -70dB. To get close to the target 1Vss output signal, an IMD3 of -55 dB without amplifier was established. The comparison of different configurations is summarized in the table in Fig. 3-6A, Fig. 3-6B shows the measurement result on the spectrum analyzer for the AD811 as an example.

Zweitonmessung Ausgang 2x4dBm	
Verstärker	IMD3 in dB
No preamp	-55,3
2SC3358 (11dB)	-29,4
AD811 (15,5dB)	-49,8
2N5109 (17dB, 10mA)	-42,5
2N5109 (20dB, 35mA)	-48

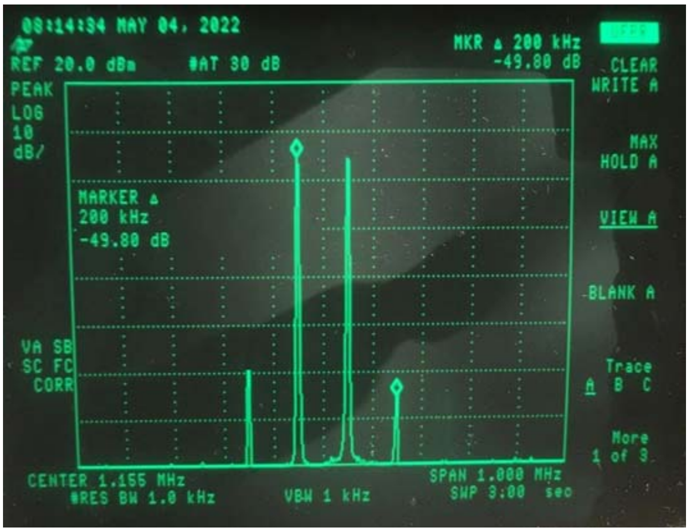


Abb. 3-6A: IMD3 results for different preamplifiers.

B: Example of a two-tone test with an AD811.

Polytron used the 2SC3358 in its MKK system at that time.

Now one should assume that the AD811 as a strongly negative feedback system with high open loop gain and bandwidth is more linear than the 2N5109. However, it showed significant cross modulation when receiving the BBC on 198 kHz through the Mainflinger EFR transmitter on 129.1 kHz. Cascading the two 2N5109s, however, yielded flawless reception without interference, even though the overall gain was 3 dB higher than with the AD811 amplifier. While the IMD3 hardly differed at a collector current between 10 and 20mA, it increased significantly above 35mA (as did the gain).

Colleague Stephan Germann (HB9LEO) wrote about the problem with the AD811 in response to a discussion post by W. Barteczek in the Wumpus Gollum forum (original in German, translated by DeepL and English proofread by S. Roberts):

> *"Hello Walter,*
>
> *Since I fell again on the pitfalls of OpAmps, I would like to describe it here, probably this is also the reason in your case, why the AD811 produces intermodulation. An OpAmp amplifier is well known to include a strong feedback system, and this is where the problem lies. If you have a signal at the input with a high enough frequency component and if the opamp open loop gain is not large is not large enough, too little signal is fed back to the differential stage via the negative feedback, with the result that the differential voltage rises and the differential stage overdrives. This turns the stage into an additive mixer, producing intermodulation. This is a well-known phenomenon, which is why every serious hi-fi amplifier has a low-pass filter at the*

input to suppress these high (inaudible) frequencies so that they do not overdrive the differential stage.

Relevant for estimating the highest frequency that an opamp can still process is not the bandwidth, but the maximum slew rate at the opamp output according to the data sheet. This must be greater than the actual slew rate of the amplified signal, a factor of 2 is usually good.

If you take a sinusoidal signal at the amplifier output with amplitude A and frequency f of the form

$$A\sin\left(2\pi ft\right),$$

then the maximum slew rate is the derivative at zero crossing, e.g. for t = 0:

$$\max Slewrate = 2\pi fA$$

The unit is V/s, so you have to divide the value by 1e6 to get the usual unit V/μs of the data sheets.

You can see here that besides the frequency also the amplitude of the amplified signal is relevant. If you take the AD811 with 400V/us for realistic output signals, you get about 30MHz at 1V output voltage and a factor of 2 as reserve. But if a strong FM transmitter is beaming in, this might cause problems. Remedy is a simple L/C low pass filter before the amplifier. Further it is to be noted also that the maximum Slewrate of the OpAmp usually decreases with rising load of the output."

Op-amps thus have their pitfalls in multicarrier systems under unfavorable conditions, which do not occur in simple transistor amplifier stages. The problem with VHF radiation and the resulting intermodulation products on shortwave bands were also observed by H. Scharfetter with his active mobile dipoles for travelling, if no prefilter is used. There the OPA656 is in use.

3.3.2.4 Wideband LNAs offered in internet

A number of very broadband LNAs are offered inexpensively on the Internet, often specified from low frequencies (100 kHz, sometimes DC) up to a few GHz. These are mostly based on MMICs which advertise very good noise figures. Unfortunately, experiences with these small boards vary widely. Some boards worked flawlessly, some oscillate at high frequencies in the GHz range, and some fail to meet specifications at all. Some also break after some time for no explicable reason. Therefore, from the point of view of the COHIRADIA team, no recommendation can be given for such amplifiers, although they work perfectly in individual cases. However, on average you end up paying a much higher price than initially hoped for, since only one part of several amplifiers will work for sure.

3.3.3 Antennas

General:
It is no secret that a good antenna should be mounted as high and free as possible. For a balanced frequency response of the LW, MW, KW frequency ranges of particular interest, an active antenna system can be helpful. Symmetrical arrangements are usually superior to unbalanced ones. Radio amateurs who are active in transmitting quickly notice whether an antenna can produce sufficient

signal level. In particular, the feeder of the antenna should be as free as possible and > $\lambda/4$ (λ=wavelength) above ground. The level of local interference sources decreases in third power with the distance, so that also in pure receive operation every metre of height counts. In the following paragraphs the antennas are described which have been used in COHIRADIA so far:

3.3.3.1 Dipole by W. Barteczek

The antenna is a 2x19m dipole at a height of 12 m, which is matched and symmetrized at the end via a 300Ω ribbon cable. If necessary it can also be used as a "quasi-T-antenna" or 2xL versus ground, respectively. On the roof of a prefabricated house on a slope, a fiberglass mast of military origin has been installed, see fig. 3-7. A 3mm steel strand 2x18.5m has been connected to the 300Ω ribbon cable at the top end without any transformation, One end goes to a fiberglass mast of the same height (with wire pulled in, tuned to 40m) to the north. Due to the slope, this part of the dipole is almost horizontal. The other dipole half is fixed in a tree at a height of about 7m. This dipole branch has a strong inclination to the south.

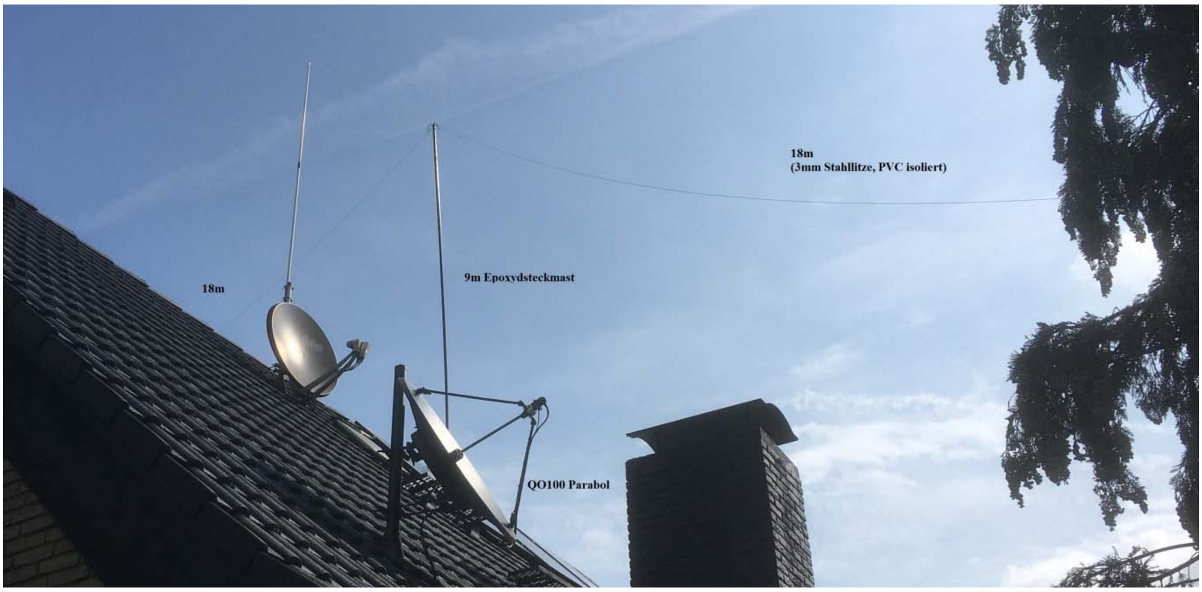


Fig. 3-7: Antenna system on the rooftop

The lower end of the standing wave feeder cable goes to the matching device shown in fig.3-8. It should be noted that this configuration must not be used with a coaxial cable.

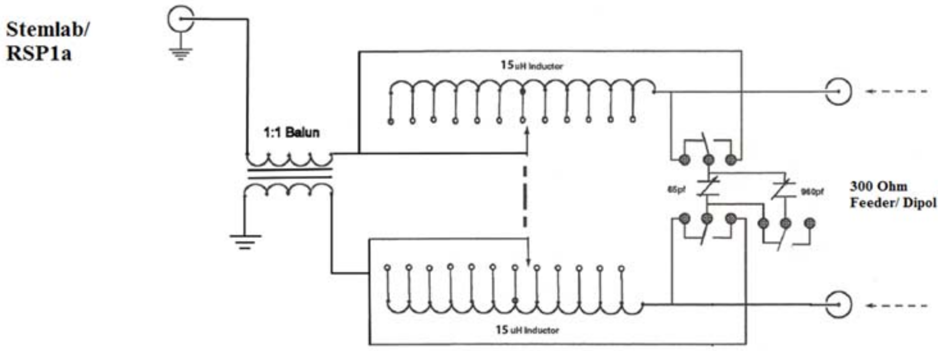


Fig. 3-8: Matching device.

The antenna is tunable in this form with good standing wave ratio between 2 and 50 MHz. Especially on LW and VLF the operation "2xL" similar to a T-antenna with respect to ground is recommended. A level registration in the Georg von Neumayer station over one week in the winter 2021 in the operation mode "WSPR" showed a clear superiority on 160m in this configuration of approx. one S-stage (6dB), in which the actual dipole works only as roof capacity. This value was also determined metrologically in the near field. For COHIRADIA, however, the dipole mode was chosen and one or two 2N5109 amplifiers were inserted. To avoid overloads from frequency ranges where the dipole can be resonant, different low pass filters can be inserted: 30kHz, 300kHz and 2 MHz. The individually and freely selectable components were integrated into a Polytron MKK system which stems from the time of the analog community antenna technology, see fig. 3-9.

Polytron used the BFR69 transistor type for its UHF amplifiers. The wideband version for 47 to 860 MHz used the 2SC3358 with a transit frequency of 7GHz, a noise figure of 2dB and a maximum allowed collector current of 100mA. These amplifiers could be configured with 12, 24 and 36dB gain in different versions. To make these amplifiers suitable for MW and LW, the chokes were increased from 10 to 330 mH and the capacitors from 1 to 100nF by W. Barteczek. While the LNAs failed due to observed cross modulation already under daytime conditions - the transmitters of the EFR data service on LW were punching through in the lower MW range - the use of the 12 and 24 dB amplifiers was still good during twilight hours, but proved to be absolutely unsuitable at midnight.

Fig. 3-9: Polytron-MKK system with amplifier modules, attenuators and filters.

3.3.3.2 Loop Antenna used by W. Barteczek

A Rohde & Schwarz HFH2-Z2 discarded from the radio measurement service is used as a loop, which is operated in the attic under the roof (Fig. 3-10) from an analog, balanced power supply and appropriate choking near the base. With a calibrated amplifier (receiver or spectrum analyzer), the absolute field strength can be determined by adding 20 dB.

Fig. 3-10: Loop antenna below the roof.

3.3.3.3 Wellbrook Loop used by G. Müller

The Wellbrook ALA 1530 Loop antenna is used exclusively for reception. It has a high directivity. This allows a more targeted signal sampling and improved reception of weak signals compared to simpler antennas. The antenna is able to receive signals over a wide frequency range of 0 - 30MHz. Due to their design, loop antennas are sensitive to the magnetic field component and are thus somewhat less sensitive to local interference signals mediated by electric fields. In addition, thanks to the directional characteristic, unwanted signals from other directions can be suppressed to improve the desired reception. The antenna is comparatively small and compact, which makes it easily portable and simple to install (see Fig. 3-11). This is particularly useful for mobile use or for applications where limited space is available.

Fig. 3-11: Wellbrook ALA1530, mounted outdoors.

Unfortunately, the production of the Wellbrook antennas was discontinued in April 2023. Since the manufacturer unfortunately does not want to publish current schematics of the amplifier circuit, the information on this is very limited. Fig. 3-12 shows the circuit of a replica published in the Italian AIR Radiorama [10].

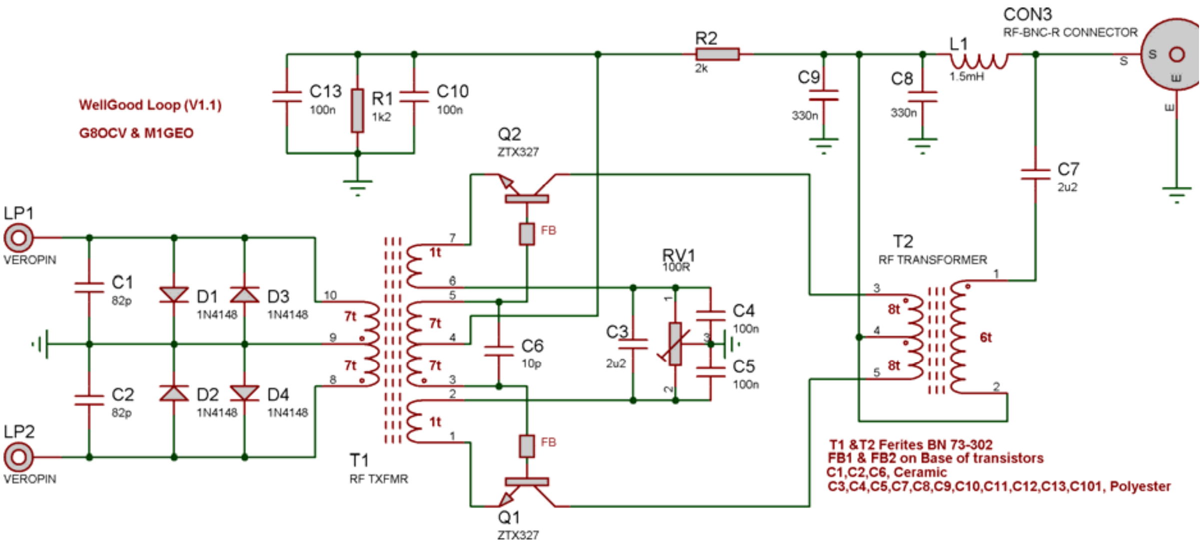


Fig. 3-12: Reverse engineered schematic of the Wellbrook loop antenna in [10].

3.3.3.4 Whip antennas used by S. Roberts

The whip antenna nr. 1 is a 1 m long telescopic antenna rescued from an old transistor radio attached to the PA0RDT circuit [3,2] using Veroboard for the circuit construction. The items are contained in a 19 mm. diameter PVC plastic pipe with end caps. The assembly is clamped to another piece of PVC pipe that is attached to a conventional photo tripod (see fig. 3-13).

There's nothing critical about this antenna and it can be built largely with components from the junk box as a sure-fire and inexpensive way to get started. For example, a BF 244/BF 245 was used instead of the J310. At 12 volts dc the gain was a little high for the RSP1A, so the antenna was powered through the Bias-T 5 volt facility directly from the RSP1A.

The whip antenna nr. 2 (since July 2023) is a special modification of the PA0RDT mini-Whip circuit [3,2] using an old National Semiconductor LH0063 integrated circuit instead of the J310/2N5109 combination. The data sheet for this IC is still available online and the schematic is included in fig. 3-15, the board is shown in fig. 3-14. This again is a junk-box antenna and the IC was chosen because it is just a voltage follower circuit so does not suffer from the feedback issue described in 3.3.2.3 above. Additionally, this particular IC was selected as it has a minimum slew rate of 2000 V/μs and the capability of driving a coaxial cable directly, so it can be looked upon as a virtual PA0RDT circuit in a TO3 can.

The antenna seems to perform very well on the photo tripod using a supply voltage of 12V. It consumes approximately 25 mA.

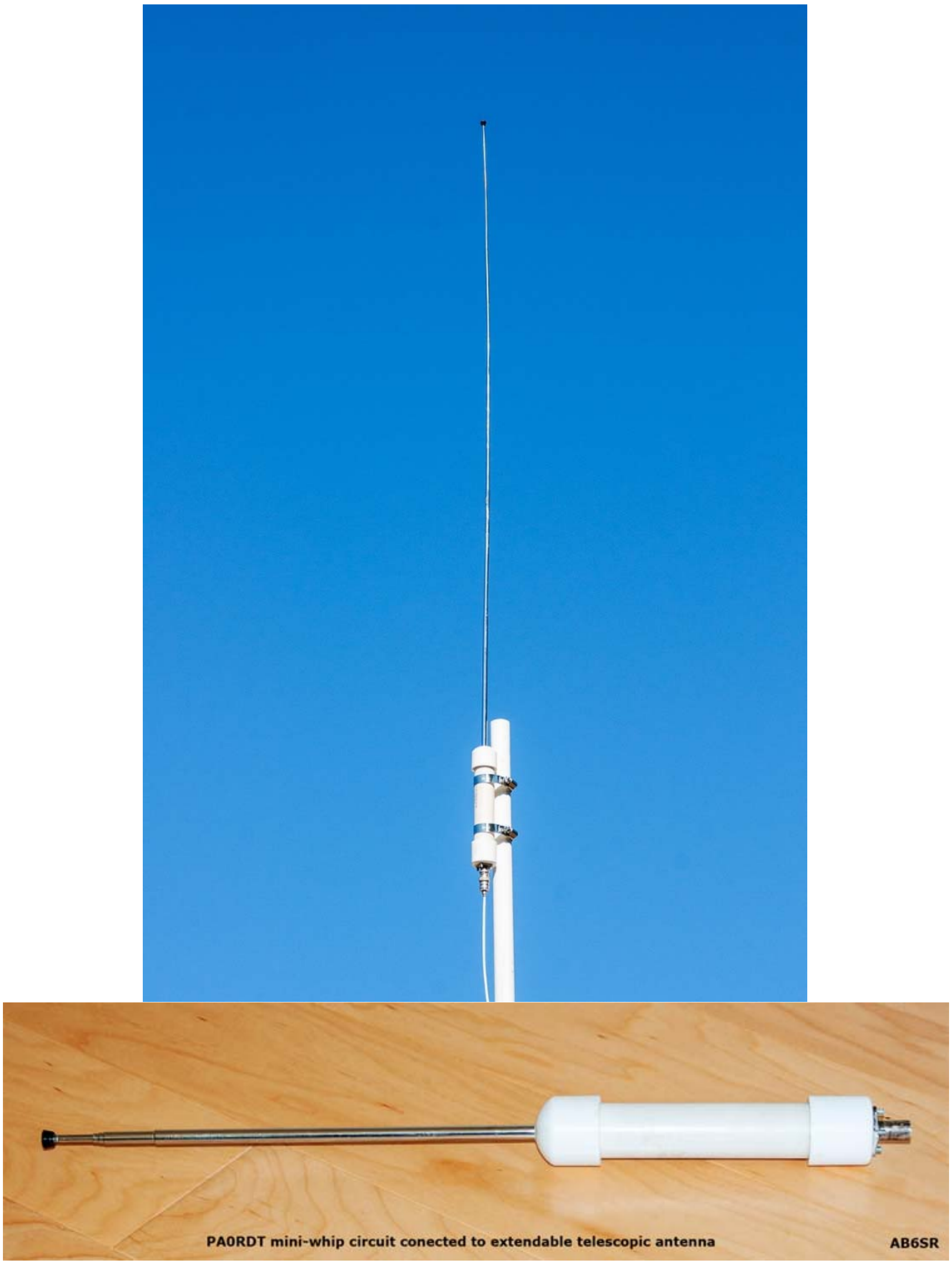


Fig. 3-13: Whip antenna nr. 1 used by S. Roberts

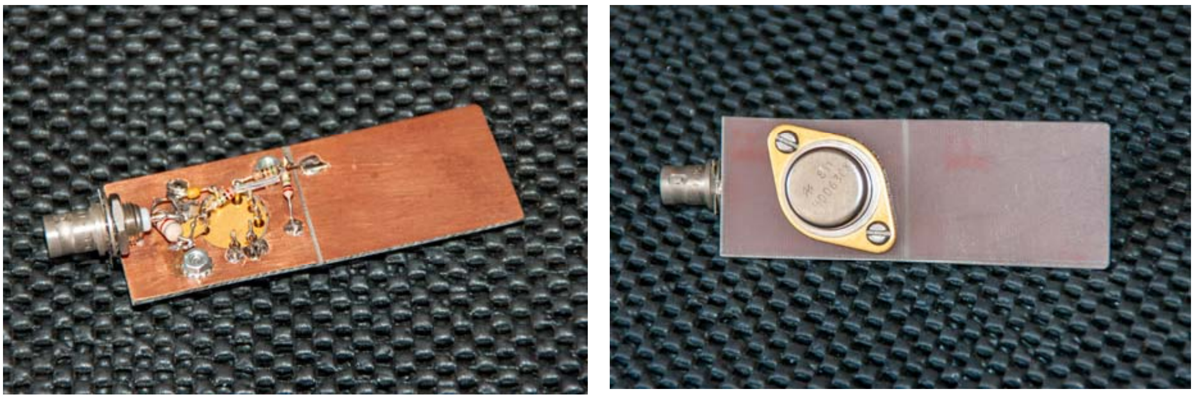
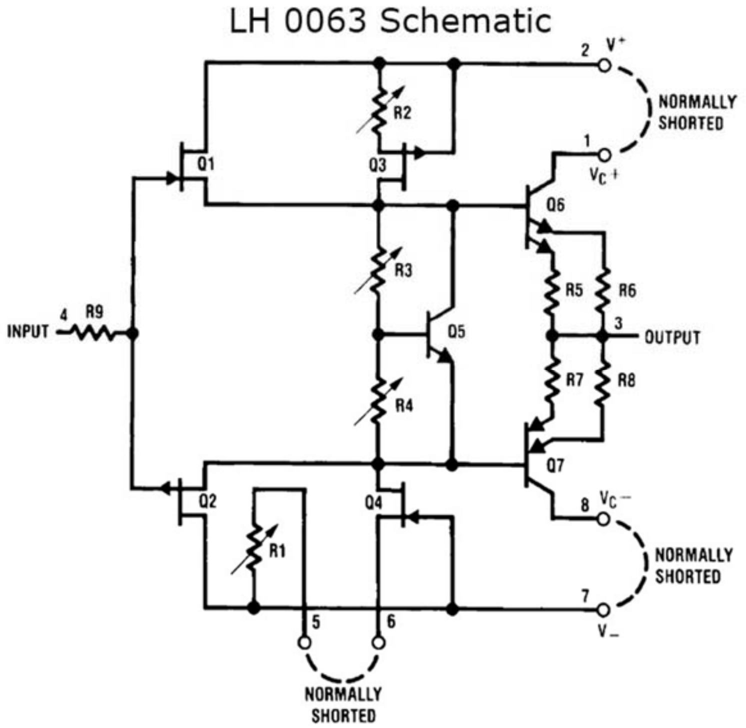


Fig. 3-14: Board of the whip antenna nr. 2 by S. Roberts

A



B

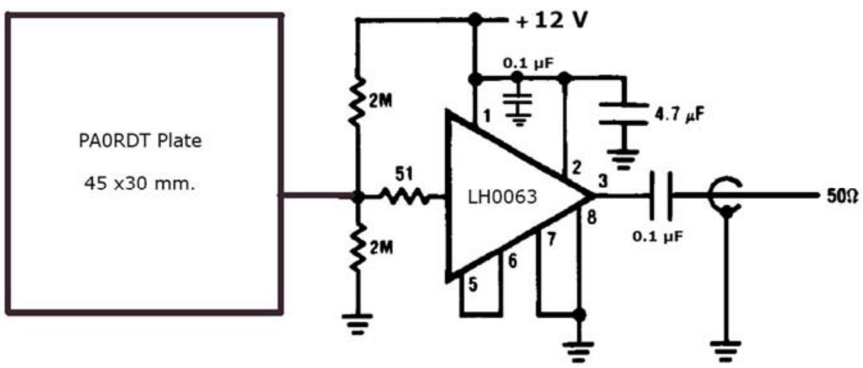


Fig. 3-15: Whip antenna used by S. Roberts, schematic.

3.3.3.5 Loop antenna used by S. Roberts

The loop antenna consisted of 10 turns of 24 AWG insulated stranded wire wound on an acrylic frame with the turns spaced horizontally by about 2 mm. This resulted in a square loop of approximately 0.5 m. per side (see fig. 3-16). A 300Ω twin feeder was used just because it happened to be available. This loop antenna was used for several recordings in 2022, but then was given to a colleague and is no longer available for COHIRADIA in the future.

Fig. 3-16: Loop antenna used by S. Roberts

3.3.3.6 Active mobile dipole, type ‚Graz' (H. Scharfetter)

Starting from the idea of the whip antenna, one sees that good noise figures can be achieved even with short antennas, provided the amplifier inputs have high impedance. In classical designs, FET transistors are used together with asymmetric (rod) antennas. These have the disadvantage that local interference sources cannot be suppressed easily. Also problems with common mode interfering signals conveyed by the downlead lines has been reported frequently. H. Scharfetter has therefore developed a symmetrical variant (dipole) by means of a differential amplifier constructed from 2 low-noise FET operational amplifiers, the circuit diagram of which is given in 3-17. U_1, U_2, R_3 - R_5 form the input structure of an instrumentation amplifier, the non-inverting inputs have bias resistors of 1MΩ and anti-parallel, low-capacitance protection diodes. The inputs are somewhat (unfortunately sometimes not sufficiently) blocked against VHF coupling by ferrite chokes. The two output voltages are subtracted by the output transformer L_5/L_6. The output impedance of 2x100Ω (R10 + R11) is transformed to approx. 120Ω, so that one can then connect symmetrically to the base station with a twisted pair cable with a characteristic impedance of 120Ω. At the far end, a balun (represented by

L_3/L_4) provides the coupling to the unbalanced 50 Ω system of the base station (LNA, SDR, ...). Balanced transmission is much more robust against common mode interfering signals than an unbalanced coaxial line. This is very important here, because the high impedance input structure is extremely sensitive to such 'backward transmitted' interference, which often causes problems with classic whip antennas.

U_4 serves only to generate an 'artificial ground', since the circuit is powered from a single 9V battery.

As antenna H. Scharfetter uses two telescopic rods of max. 120cm length each. This arrangement has a dipolar directional characteristic and can often suppress local QRM fairly well if properly aligned. The antenna is also directionally sensitive to ground waves received during the day because of their relatively well-defined polarization, while space waves reflected from the ionosphere at nighttime are naturally received much more non-selectively.

As already discussed in the section on preamplifiers, strong FM signals from local stations may well lead to unwanted intermodulation if no suitable prefilter exists. However, such filters cannot be designed with conventional filter design tools because they require a low impedance termination. But this is not given by the high input impedance of the amplifier. The dissipation of the RF-energy in the stopband is therefore not easy and design rules cannot be given at present. Through trial and error, symmetrical L-C configurations have been found with useful success, and optimization is still in progress.

The first version 1.1 was equipped with the OPA656 (see fig. 3-17), which is a relatively broadband low-noise FET opamp.

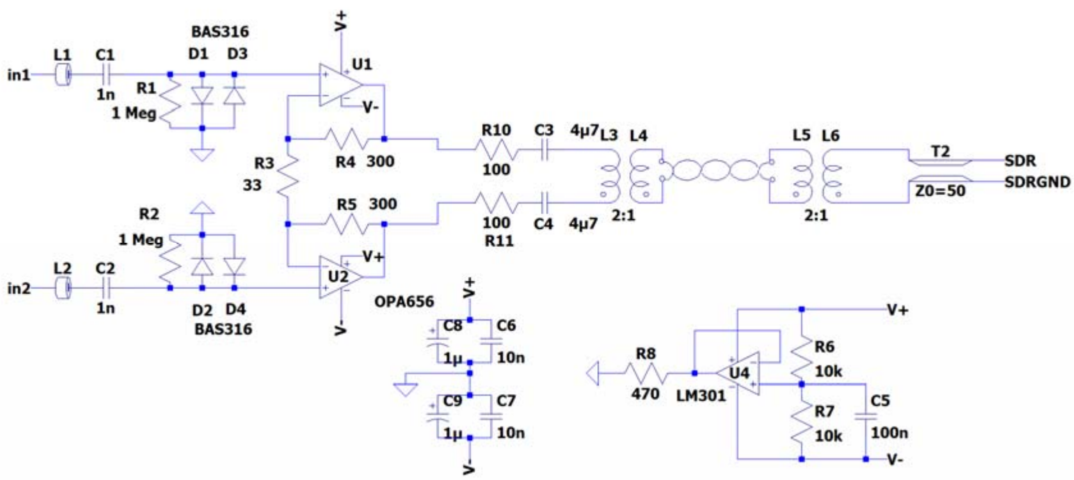


Fig. 3-17: Symmetric active dipole amplifier with high impedance inputs.

Since the cores of the transformers made from material 43 have a relatively high conductivity, capacitive coupling of interference can unfortunately not be completely excluded. In the Graz setup it turned out to be helpful to connect the ground of the 50 Ω line after the base balun L_3/L_4 to the metallic mounting platform on the roof and suppressing interfering VHF signals by a common mode choke as close as possible to the amplifier output. This choke was made from material 61 ferrite and reduced spurs from a nearby VHF transmitter considerably.

In an adapted version 2.x from 06.11.2022 the output resistances of the OPAs were reduced to 60Ω and the transformer L_5/L_6 was adapted to 1:1. A variant without transformer (two-wire line was connected directly) also works.

The signals received with this antenna have very good SNR, therefore this dipole was used for many recordings from 2022. Since the design is very compact, this system together with a RSP1A also found repeated use for mobile application, for example, on trips to Greece, Germany, etc. The antenna is deliberately not fed with a phantom circuit, but has a 9V battery built in. To switch it off and on, a toggle switch is used when traveling, but on the roof of the apartment building in Graz an optical switch is used, which is operated via an optic fiber from the base station, so that no interference is coupled in via additional cables.

3.3.3.7 ‚Graz' type home-brew Lo-Z loop antenna

H. Scharfetter also started experimenting with loop antennas in 2022. The first variant was a do-it-yourself model with a low impedance preamplifier (current-voltage converter), which is also based on operational amplifiers. However, the bipolar AD797 is used here because it is lower noise than a FET type for this mode of operation. The circuit is shown in Fig. 3-18. As with the active dipole, the signal is transmitted symmetrically to the base station via matching transformers and a balanced twisted pair with a characteristic impedance of approx. 120Ω.

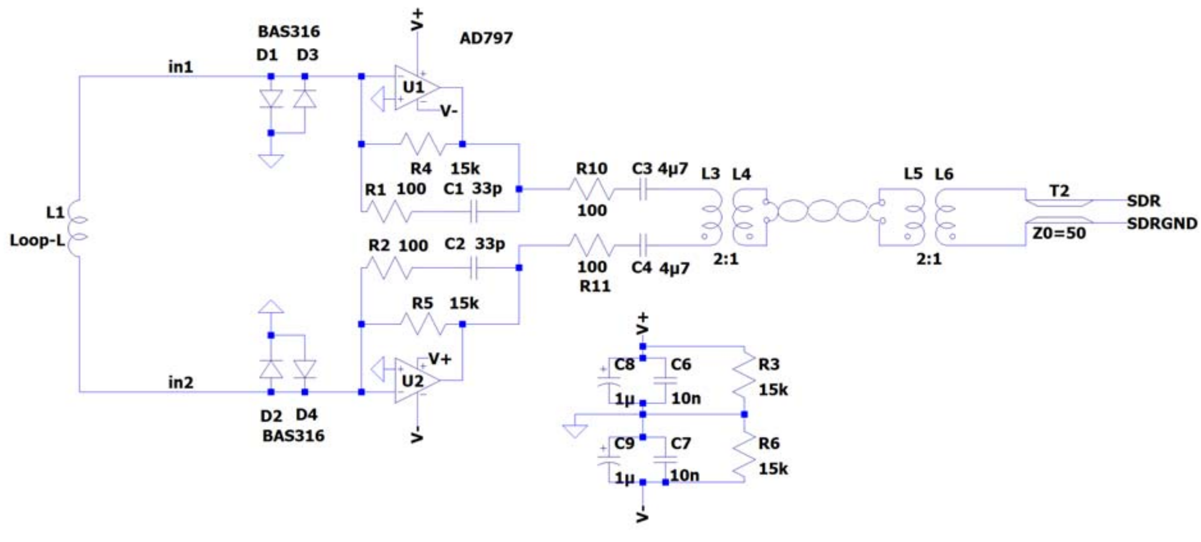


Abb. 3-18: Symmetric loop amplifier (current-voltage converter, i.e. transimpedance amplifier).

3.3.3.8 Loop Wellbrook ALA1530Flex used by H. Scharfetter

Inspired by excellent recordings made by G. Müller, H. Scharfetter has been using a Wellbrook antenna in the 1530Flex variant since late 2022, which has no preamplifier permanently mounted on the loop, but where the amplifier section is housed in a separate box. The loop was improvised with 2 turns of copper wire in a hula hoop, and the set provides excellent signal quality. Fig. 3-19 shows a deployment in Portoroz (Slovenia), where the directional sensitivity of the loop was very important. In order to significantly reduce the signal from the MW transmitter of Beli Kriz, which is only a few km away, the loop was turned to locate the minimum of the very strong signal. Otherwise, the transmitter would have restricted the dynamic range too much for the rest of the medium wave. The Wellbrook LNA was operated for VLF recordings (e.g. transmitter Grimeton on 17.2 kHz) with a homemade approx. square frame antenna with 1x1m and 7 turns of thick stranded wire. This combination resulted in slightly better SNR values compared to the hula-hoop loop and the active dipole and is meanwhile used for most recordings made by H. Scharfetter.

Fig. 3-19: Deployment Wellbrook 1530Flex with homemade loop on a houseboat in Portoroz (Slovenia) 2023. The amplifier part is the small box just below the loop, the bias tee and power supply are on the case on the bottom.

Fig. 3-20 shows all three antennas currently used by H.Scharfetter (active dipole, Wellbrook 1530 and home-made loop amplifier together with the two home-made loops in hula hoops on the roof of his house. One of the two loops often serves as an auxiliary antenna in a QRM canceller circuit with a QRM canceller from WIMO.

Fig. 3-20: Active dipole and two loops mounted on spiderbeam telescope masts on the roof.

3.3.3.9 Mobile COHIRADIA-Set

The mobile set of H. Scharfetter already used at different places in Europe consists essentially of a SDR (mostly RSPdx or RSP1A), a small laptop, an extendable fiber reinforced telescopic mast (Spiderbeam from WIMO), the active dipole and if necessary also the Wellbrook1539 Flex as well as a box for various adapters, filters and cables. Fig. 3-19 - 3-21 show some photos of operations between 2022 and 2023. A small gas soldering iron usually must not be missing either, as there is always something to repair. Until the end of August 2023 a variant of the active dipole was on the road in New Zealand, where a work colleague kindly took records during his vacation. At the same time, a mobile combination of loop and active dipole was successfully used in Sweden, which found room in the travel suitcase for the flight.

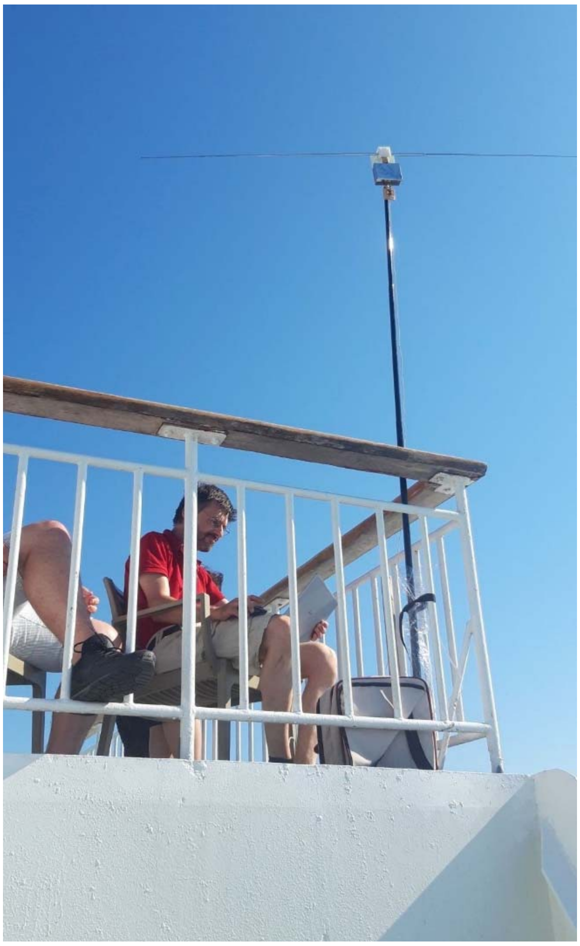


Fig. 3-21: Recording with the mobile dipole on a ferry in the Adriatic sea 2022

Fig. 3-22: Recording with the mobile dipole in northern Greece (south of Igoumenitsa) 2022

4 HISTORICAL METHODS: VTR

Between 2006 and 2009, H. Scharfetter made his first analog broadband recordings with a Philips VR6711 video recorder, which still allowed manual tracking. At that time about 15 videotapes were recorded with MW and partly also (after downmixing) with shortwave (SW) broadband signals. Unfortunately, no very good antenna and preamplifier were available at that time. The input structure consisted only of an approx. 5 m long wire, a self-made LC band filter of 4th order for MW (500 - 1700 kHz, Chebyshev characteristic) and the amplifier of channel 1 of an analog oscilloscope, type Kenwood CS-5135 (40MHz).

A transistor stage as shown in Fig. 4-1 was used as the mixer, with the bias set via P1 so that the 3rd order intermodulation product was maximum. C4/L1 served as a simple high-pass filter for LW and MW suppression. An old Philips GM2883 tube RF generator served as the local oscillator for the 'LO' input. At input 'RF' the antenna signal was fed in, 'IF_out' was then again amplified by the oscilloscope to 500 - 700mVpp.

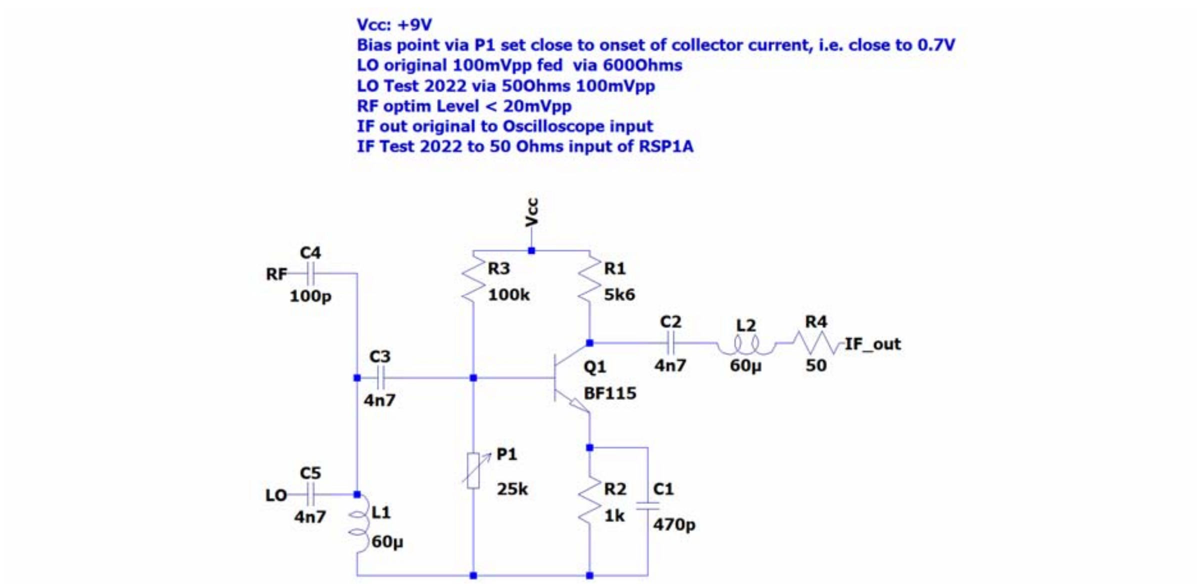


Fig. 4-1: simple mixer with single transistor.

Some of the tapes were digitized with the STEMLAB 125-14 from 2021 on, the originals are stored in Graz. They can still be played back with video recorders, in which case the video-out signals can be coupled directly (via the RF transformer) to the antenna input of radios.

This recording technique had a number of serious weaknesses:

- The usable dynamic range of the VTR was probably no better than about 50dB, according to the service manual the video SNR is 'more than 43 dB'. Thus, only relatively strong incident transmitters could be well recorded. Intermodulation immunity was probably not very high, but has not been quantified. This often resulted in mixing of strong transmitters to other carrier frequencies.

- Unfortunately, all video recorders used play the tapes at almost 3% higher videohead speed than when they were recorded, presumably because of the lack of synchronization by a video signal. As a result, all carrier frequencies appear increased by this 3%. This deviation was largely corrected for COHIRADIA by digital resampling, but there is still a residual, small frequency deviation in these recordings. Also, the frequencies fluctuate periodically due to control variations of the head drum speed. Therefore, it is practically impossible to decode the DRM signals broadcast on some frequencies at that time.
- The signals contain periodic disturbances in time with the video frame rate (takeover gaps when switching between the two video heads), which are noticeable as a slight 'chatter' in the background. By the way, these disturbances can also be heard clearly on the analog recordings in the archive https://spectrumarchive.org/, so it was a very characteristic phenomenon.
- The signals mixed down from shortwave into the usable frequency range of the VTR do not have good frequency stability, since the analog local oscillator without digital frequency display did not allow very precise adjustment. For digital resampling, therefore, synchronization was made to individual transmitters whose frequencies could be reconstructed from historical tables.

All in all, the recordings made with this technology are not of very good quality, but because of the content they were nevertheless stored in the archive. After all, there are still quite a few German radio stations, Vienna Bisamberg on 1476 kHz, 'Option Musique' of the Swiss station Sottens on 765 kHz as well as quite a few French stations which, as is known, stopped their service a little later.

5 SOFTWARE:

5.1 INTRODUCTION

At the time of the start of COHIRADIA, a software application programmed under Python called 'RFCorder v1.1' was made available at the Radio Museum by H. Scharfetter, which allows play back of wideband recordings by means of the STEMLAB 125-14. This is the only publicly available software known to the author to date that allows recording and playback of wideband data on analog radios. However, alternatives are certainly conceivable and feasible. For pure recording, several SDRs plus the respective available software are suitable, as described in section 3. Since the STEMLAB 125-14 is the only system that has been fully tested for playback, extensive further development of the RFCorder is planned. This is necessary, because version 1.1 is still very limited in its functionality, especially concerning supported file formats, computer platforms and sampling rates. Therefore, the corresponding issues are described below.

5.2 FILE FORMAT AND NAME CONVENTION

At the time COHIRADIA was launched, no research had been done on alternative SDRs. Therefore, the file format used in the development of the RFCorder did not conform to any established standard. The sampled data was stored as raw binaries as passed to the RFCorder by the API provided by Pavel Demin (RedPitaya) during communication with the STEMLAB 125-14, namely as a stream of complex integers with 2x16 bits per sample and the sequence 'real - imaginary'. This corresponds to the raw IQ format, as can be read in [14], where data file formats for IQ are being described. For those interested: Details about IQ sampling can be found e.g. in [7].

After gaining some experience with the RSP1A it became clear that most considerable SDRs, which are usable in the context COHIRADIA, store the data as wav files. However, unlike standard audio files for which this format is normally known, SDR data has a much longer header in which a whole range of metadata is encoded. This is followed, as with RFCorder, by a stream of complex integers. Several systems like SDRUno use exactly the same bit sequence as the RFCorder, so that the files differ only by the header. Thus it is very easy to turn an RFCorder file into a wav file readable by practically all other systems, if the header format is known. This format was kindly provided by SDRPlay on request. However, to keep the world not too simple, some SDRs, like earlier versions of PERSEUS, encode the header slightly differently and some write 2x24 or 2x32 bit complex data instead of 2x16 bit. Such recordings can sometimes be found in the archives mentioned in Section 1.3. The RFCorder of versions 1.1 and 1.1b cannot handle these formats, so the files have to be converted first (this is currently only possible on request to H. Scharfetter). Furthermore the software expects a special structure of the filename, namely: [ARBITRARY_NAME]_lo####_r####_c#.dat. lo#### encodes the frequency of the band center (i.e. the local oscillator LO) in kHz, _r#### the sampling rate in kS/s and c# stands for a frequency offset which was never used so far, being set always to zero. #### are appropriate integers.

It should be mentioned that the uncompressed raw data are stored, since the authors are currently not aware of a lossless standard compression program. It might also be difficult to develop such a program for this special signal type, because for example the noise and interferences belong to the 'original sound' and must not be 'compressed away'. Therefore the files are unfortunately very large (see comparison of wav and mp3 files for audio files). The choice of 16 bit as default bit depth is based on the SDRUno used by SDRPlay, although higher bit depths (e.g. 24) can be discussed. 16 bit has so far proven to be a viable compromise between dynamic range and file size usable for most cases.

5.3 Sampling rates

The code smippets provided by Pavel Demin for data transfer to STEMLAB allow only certain fixed sampling rates, namely: 20, 50, 100, 250, 500, 1250 and 2500 kS/s. The possible recording bandwidth corresponds to the same values in kHz. With 1250 kS/s, the medium wave band can be comfortably recorded (e.g. from 500 - 1750 kHz). Also SW and LW bands can be imaged well (LW more than sufficient with 250kS/s, the 49m band with 500kS/s).

As long as only files also recorded with the STEMLAB are played back, the limitation is no problem. Unfortunately other SDRs frequently use different values. The RSP1A, for example, fortunately uses the 1250 kS/s for MW, which comply with the STEMLAB. For LW, however, the default value is 150 kS/s, which cannot be played back with the STEMLAB. In addition, individual settings are also possible. External archives very often contain recordings with sampling rates not playable by STEMLAB. This incompatibility is of course a problem for COHIRADIA in the medium term. Therefore the author has already written a resampling program under MATLAB, which allows recoding files with arbitrary sampling rates into one of the STEMLAB rates (resampler). The program uses the extremely versatile open-source tool 'sox'. It is also possible to cut out certain spectral regions from bands that are too wide. However, the program is not publicly available, so conversions can currently only be made on request. Therefore, a transfer of the code into a Python program is currently in progress, which will be publicly downloadable later in 2023.

5.4 Software for SDRs:

The COHIRADIA files can also be played with alternative SDR software. The tools tested so far are:

5.4.1 SDR#: https://airspy.com/download/

sdr# can be installed with the community plugins (https://airspy.com/download/), the plugin Rtl433-for-SDRSharp can be installed afterwards, if required.

If the COHIRADIA *.dat files are just renamed to *.raw, they can be played back with the option 'Baseband file Vasili' after choosing the sample rate, 16bits per sample and channels = 2.

Vasilis Installer-Page: http://www.rtl-sdr.ru/page/novyj-plagin-file-player

Further info see https://www.rtl-sdr.com/new-sdr-plugin-file-player/

5.4.2 SDRUno

SDRUno is the software for the products of SDRPlay, such as the RSP1A. The interface is professional, but at the beginning it takes a bit of getting used to and some important functions can be found only after one has dealt extensively with the tool. Practically all common wav formats can be played back with this software, but the COHIRADIA *.dat files are not supported. Therefore the insertion of a wav header is necessary in this case. A detailed documentation can be found on the webpage of SDRPlay.

5.4.3 RFCorder

A detailed description of this program, which is only available as an exe file for Windows10, can be found on the COHIRADIA landing page, from where the installation files can also be downloaded. Fig. 5-1 shows the user interface of the RFCorder.

The program requires a STEMLAB 125-14 connected to the LAN interface, with an SD card on which the operating system (Ubuntu) provided by Red-Pitaya with the latest updates is installed. The installation of the correct drivers and server files can then be done using a script by Ueli Kurmann as described in the installation guide.

Compared to professional SDR programs, the tool is limited to the most necessary elements for playing and recording the RF signals, auxiliary displays like a display of the spectra or waterfall plots are missing as well as a direct audio playback or preconfigured buttons for the various AM bands. The user has to set details like center frequency and bandwidth by himself/herself. The actual recording time is not displayed, only the time played from the beginning. At least the program allows the automatic start of a recording by means of a timer. A special feature is the possibility to shift the frequency band in the spectrum during playback, e.g. to play a long wave band in the medium wave range of a radio. For this, an offset to the band center frequency must be specified.

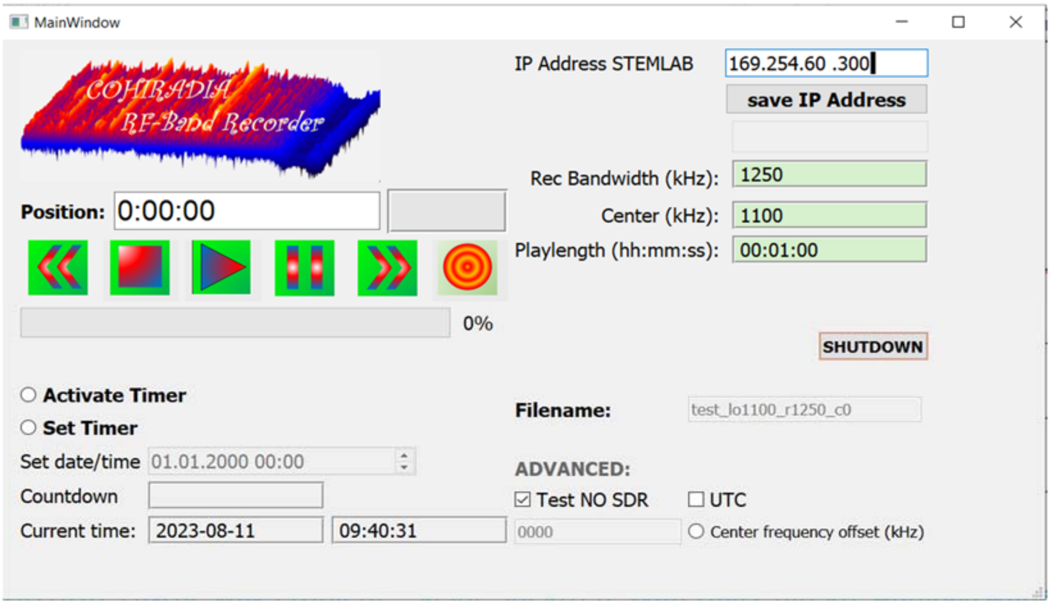


Fig. 5-1: User interface of the RFCorder v1.1b.

The source code of the program is basically available on GITHub, but the program was created relatively 'quick and dirty' and does not meet a very good programming standard. The documentation is also very rudimentary and not yet complete. Since it is not expected that this software version will be further developed, no further maintenance is planned and the program must be seen as a temporary initial solution. Use under LINUX is theoretically conceivable after installation via GITHub by an experienced person, but this has not been tested.

Required for the tool is a STEMLAB 125-14 (optionally maybe a 125-10), an SD card with the operating system (Ubuntu) after upgrade, as well as the server installation with the installation script of Ueli Kurmann. Detailed information is available on:

https://cohiradia.radiomuseum.org/download/docs/COHIRADIA_users_guide_V3_en.pdf.

5.4.4 Continuous (repetitive) playback tool fort the command line

On request a very simple version was programmed, which can be started only on the DOS command line without a graphical user interface and is available on the landing page as COHIRADIA_playback_endless.zip.

Alternative software packages, such as GNURadio, have not yet been tried.

5.5 COHIRADIA-INTERNAL ANNOTATOR (COHIWIZARD)

A more universal software ('COHIWizard') written by H. Scharfetter has been made available to the current active COHIRADIA participants as a beta version for internal testing. This tool has a playback function like the previous RFCorder, but can already handle wav-files. Furthermore, there is a first possibility to resample recordings with sampling rates unsuitable for STEMLAB. Additionally, an annotation tool is built in, which can help to generate the metadata files semi-automatically. However, this feature currently only works for Europe, as the database for other continents has not been built in yet. A screenshot of the interface of the annotator tool can be seen in Fig. 5-2.

Furthermore, a monitor for the band spectra is available, which allows a quick static evaluation of recordings. A general release of a beta version of this software for testing purposes is planned for the end of September 2023.

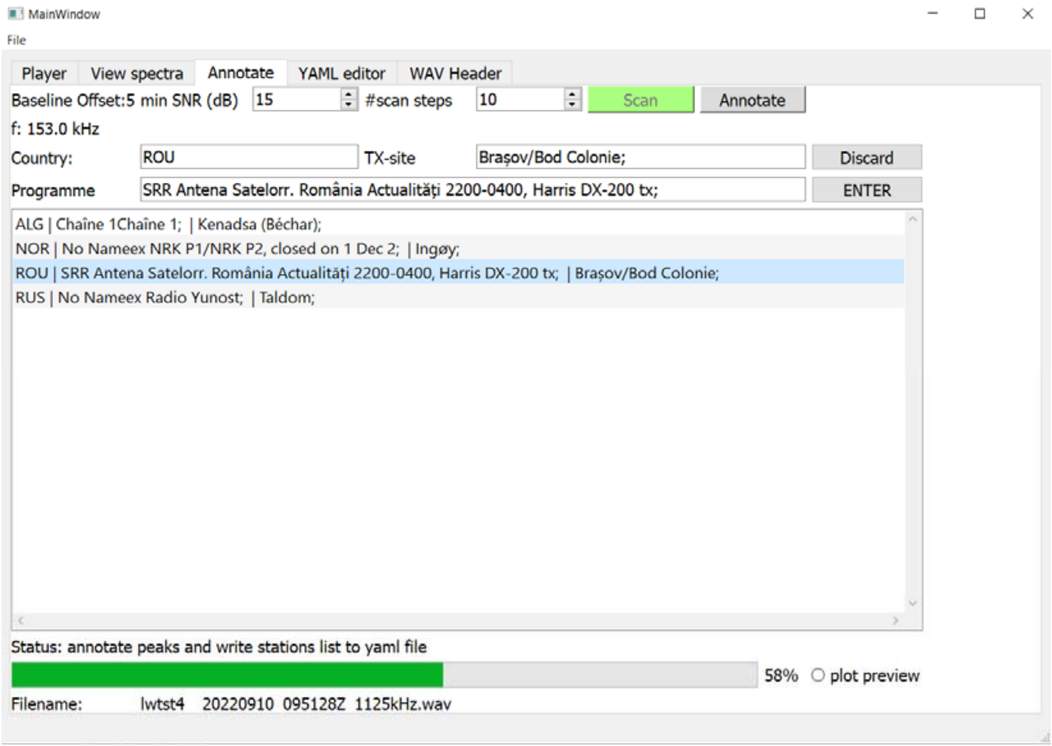


Fig. 5-2: Screenshot of the COHIWizard in annotation mode

5.6 CONCLUSION

If the COHIRADIA files are to be useful and attractive for users of the RFCorder, and be usable with various SDRs, then it is necessary to offer them in wav format in future. This requirement is also necessary if COHIRADIA files are to be compatible with external archives.

Since a new release of the RFCorder will take some time due to time constraints, Ueli Kurmann has thankfully taken the trouble to integrate a Java-based converter into the COHIRADIA landing page as an interim solution. This converts the files immediately during the download into the format desired by the user (*.wav or *.dat). We would like to thank Ueli for his efforts and his fast and perfectly working solutions.

Unfortunately this provisional solution does not yet allow playing files from external archives directly because of the sampling rate problem. Only COHIRADIA files can be used so far. The solution of the problems is planned by a gradual extension of the RFCorder software.

There will be two parallel versions in the future:

1. COHIWizard: An advanced version for users who actively record. Includes a complete record/playback unit as well as tools for annotation, resampling (including cutting functions both in time and spectral domain), editing wav headers and metadata.

2. RFCorder: A minimal version for users who only want to playback. Structure similar to the current RFCorder, but with full functionality for wav files and possibly with simple resampling function.

A preliminary expansion plan is:

Planned software	Functionality	Planned release
RFCorder v2.0	• Playback of wav files with STEMLAB compatible sampling rates; • Simple resampler for files from external archives with other sampling rates	October 2023
COHIWizard v1.0	• Complete functionality of RFCorder v2.0 • Editing and inserting wav headers; • semi-automatic annotation of recordings (metadata generator) for Europe.	End of October 2023
COHIWizard v1.1	Extended resampling for single wav files	November 2023
RFCorder v2.1	• Recording in wav format • Extended resampling for single wav files	November 2023
COHIWizard v1.2	Resampling of whole sets of wav files	End of December 2023

5.7 Open Source And GITHub

5.7.1 General:

Version 1.1b of the RFCorder is available as source code on GITHub at https://github.com/hermy-sf/COHIRADIA_RFCorder, but the repository is currently not very well maintained. The documentation is still poor and the docstrings in the code only partially comply with the standards. It must also be admitted that the code was written rather 'quick and dirty' and amateurishly rather than according to all rules of software development. The author is self-taught in Python and therefore a complete re-design of the software would be more than in order. However, it is unclear whether a new edition of the RFCorder with the existing interface will come. More likely, the recording/playback unit will be incorporated into the new COHIWizard, which will also include an editor for the wav header and an initial annotation tool, as well as a rough analysis tool for the spectra of the recordings (quality control). A corresponding repository at the time of the COHIWizard release is planned.

5.7.2 Open-Source licences:

The code parts by Demin Pavel have been published under the MIT license →

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COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER
IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN
CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.

The license for the RFCorder (and all other planned programs) must be GPL, because PyQT is used and almost all modules of this package are released under LGPL or the parent GPL license.

6 REFERENCES

[1] Analog Communication - SNR Calculations: *https://www.tutorialspoint.com/analog_communication/analog_communication_snr_calculations.htm*

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7 ANNEX

7.1 METADATA STRUCTURE OF THE YAML-FILES FOR ANNOTATION OF THE RECORDINGS

The following listing shows a typical yaml file, where three sender blocks with randomly selected senders are inserted as an example (in dark blue). Fields marked with ### must be entered user-specifically in any case. The COHIWizard supports the automatic generation of this file.

```
id: automatically generated by the server
uri: "###Folder name in data directory of COHIRADIA
server/filename.wav"
recording-date: "2022-09-10T09:50:58+###UTC OFFSET###"
duration: 30.0
band: "### LW - MW - SW - others"
frequency-unit: "kHz"
frequency-low: 55.0
frequency-high: 305.0
frequency-correction: 0.0
encoding: "ci16"
center-frequency: 180.0
bandwidth: 250.0
antenna: "### brand/type of antenna"
recording-type: "### SDR type or other devices"
remark: "### Notable details in the spectrum "
content: "### Title of the recording as it appears in the COHIRADIA
list"
radio-stations:
- frequency: "531"
  snr: "50"
  country: "ALG"
  programme: "Radio Algerie Internationale"
```

```
  tx-site: "F'Kirina"
- frequency: "540"
  snr: "55"
  country: "HNG, off air after 20:30 UTC"
  programme: "MR1 Kossuth Radio, off air after 20:30 UTC"
  tx-site: "Solt"
….

location-longitude: "### RX coordinate"
location-latitude: "## RX coordinate"
location-qth: "### alternative to RX coordinates"
location-country: "### RX Country"
location-city: "### RX CITY"
upload-user-fk: "### RM ID if any"
filters: "### used filters between antenna and recorder"
preamp-settings: "### preamplifiers: type and settings"
```

7.2 DEFINITIONS IN THE CONTEXT OF 'DYNAMIC RANGE'

Citation (from https://www.rp-photonics.com/decibel.html):

Some frequently used related specifications are:

- *dBc = dB relative to the carrier. This is used e.g. to specify the power of a sideband in a modulated signal relative to the carrier. For example, −30 dBc means that the sideband is 30 dB below the carrier, i.e., it has a 1000 times lower power.*
- *dBc/Hz: This is used for noise and means dBc in a 1-Hz bandwidth. (Of course, this does not mean that there would be twice as many dBc in a 2-Hz bandwidth, as decibels are a logarithmic measure; therefore an interpretation as "dBc per hertz" would not be appropriate!) Often, such specifications are calculated from measurements based on a larger bandwidth. For example, if one obtains −25 dBc in a 1-MHz bandwidth, this converts into −85 dBc in 1 Hz, i.e., −85 dBc/Hz. The 60-dB difference reflects the bandwidth reduction by a factor of 10^6.*