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--and for those who prefer to build rather than buy, the following is lifted from the second edition of A DXer's Technical Guide:

Designing and Building Your Own MW Receiver

Building your own MW receiver is not a job for the faint-hearted; designing your own as well obviously involves a fair deal of technical knowledge. But if you start with building and tinkering with such accessories as audio filters, loop antennas, preselectors, and simple receiver modifications, you may find that the bug has bitten you, and that you want to go all out to try to build your own receiver from scratch. Beyond the simple feeling of accomplishment in making something that really works, there is also the distinct possibility that you can build a receiver that outperforms professional models costing a great deal. The reasoning behind the foregoing statement is simple: no commercial designer can find a large enough market to justify creating a super MW receiver, so MW DXers have had to make do with general coverage models which may or may not provide good MW reception no matter what they cost. An experienced "specialty" DXer knows what he'd like a receiver to do; he'll be lucky to find an off-the-shelf model that will do it, as manufacturers must cater to the widest possible variety of listening tastes. So, the basement tinkerer may just be able to make a MW receiver that will outperform the R-7A at a fraction of the cost.

Integrated circuits are a good place to start in building your own receiver. Ambit International, 200 N. Service Road, Brentwood, Essex CM14 4SG offers a few IC's which contain virtually an entire receiver on a chip, together with application notes; they also offer some reasonable IF filters. A MW receiver could be built with one of these ICs, but the capabilities of the set will be limited by the chip design. Still, it should be possible to build a reasonable set with digital display (using the PCIM177 for example) and 3 kHz IF passband for about the price of a good AM/FM portable, and most of the cost would be in the readout and the IF filter. Shipping IC's from Britain is a bit of an inconvenience, but there doesn't seem to be an appropriate N. American supplier.

You could use only portions of an IC (the IF amplifier/AGC for example) to get full benefit of the IF filter's ultimate rejection, or use specialty ICs, such as audio amplifiers, IF amplifiers etc. (see "The Crudley-Bathbrush 26" IRCA reprint M-24 for example. Specialty IC's are more easily available from N. American companies.) And of course, creating circuits which vary from those recommended for the IC, in order to suit your own purposes, is part of the challenge. For example, some form of preselection is necessary when building simple receivers if you plan to use an untuned random wire in an urban area.

Of course, unless one is an expert on an integrated circuit and what goes on inside it, there are definite limitations to what you can do by changing around external components. If an IF amplifier, for example, is not entirely satisfactory even after tinkering with it, then you may want to build an amplifier which uses discrete components, or simpler ICs. Although the building and tinkering will become more complex, you have more control over the action of the circuit, and a greater variety of options--for example, it's not often easy to switch AGC action off in a full receiver IC. So, we'll now proceed back from the loudspeaker towards the antenna of an imaginary homebrew receiver, and make a few points as to what would be desireable in the various stages. The reader is, of course, encouraged to disagree, and to make suggestions as to what he would find most useful in each stage. Some of these ideas are purloined from Practical RF Communications Data by M.F. DeMaw, which has a fine section on receiver design.

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The audio amplifier......Once your weak DX signal has struggled to your antenna and been generally mangled about in your receiver, you really can't afford to add distortion to it in the audio stage. A number of the power audio amplifier ICs can provide remarkably clean amplification, especially compared to the vacuum tube amplifiers in the big receivers of yesteryear. But you must remember the maxim of the hi-fi audio designer that you should have a lot more power available from the amplifier than you will ever use. This way, the amplifier will always be operating at a low level of distortion. Remember that a lot of IC's have power ratings given a 10% total harmonic distortion. Some feel that the best bet for low distortion is use discrete devices rather than IC's for power audio amplification (see DeMaw and Hayward's Solid State Design for the Radio Amateur), but perhaps see how an IC works for you first. Unfortunately, some ICs distort at very low signal levels as well as at high levels.

Audio filters can be placed before the audio amplifier if so desired, but again should be designed for minimum distortion. High pass, low pass, notch and peaking filters all have their uses, although it's usually a good idea to "process" the signal as much as possible before the receiver's detector.

The detector......That old stand-by, the half-wave diode envelope detector does a pretty reasonable job under many circumstances. If somewhat more output is desired, it can be obtained from a full-wave diode envelope detector, however. Such detectors do not provide amplification (in fact, there's some loss) but if you have a strong IF amplifier, you probably shouldn't need a detector which delivers an amplified audio output. In the interest of minimal distortion, particularly when tuning to one sideband of a signal, it might be an idea to look into some form of synchronous detection. Like many improvements to basic receiver circuits, the synchronous detector will be a better circuit to use only in some cases. But like many improvements, if you want the best possible DX, it is worth looking into. Exalted carrier techniques might also be investigated.

The IF amplifier....As state-of-the-art receiver designs now use little if any amplification between the antenna and the IF filter, it is of importance to have an IF section capable of high gain, yet one which avoids feedback problems, or distortion of the desired signal (from over-amplification and clipping). The first problem is often met by using high gain IC's, but with careful wiring on a PC board to avoid instability, with perhaps shielding and worthwhile decoupling between stages. The second problem is met by using strong AGC action which can start for signals as weak as a few microvolts. In the past, delayed AGC (where the gain control action doesn't start until the signal is quite strong) has been suggested when listening to weak signals to avoid the distortion which usually accompanies the conventional methods of reducing gain in an amplifier. However, some IC's (the MC1350 and MC1590 for example) show minimal distortion when AGC voltage is applied properly to them, due to their unusual design. AGC is applied to the IF amplifier only, as there is usually no RF amplifier necessary at MW.

AGC......In the past, it's been thought best to DX without any AGC at all, and to use a manual gain control to keep the receiver from overloading in its IF stages. To a degree, this is still true. A DX signal may be hampered by noise or splatter bursts, yet still be marginally readable. With AGC, the receiver will lose gain every time there's strong interference, perhaps limiting the readability of the DX still further, especially if the AGC has a long decay period (as the original R-1000's did). In such a situation it's better to ride the gain control, and forget about AGC. When AGC is used, it should have a fast attack time, but the decay time should be variable in order to handle different situations, such as a fast SAH or flutter on a desired signal, or in bandscanning. Experimentation is in order here.

An S-meter is usually associated with the AGC circuitry, and may be just a simple tuning indicator, useful for nulls and relative signal levels. A true signal strength meter, with well-defined differences in signal strength between different meter readings is rather more difficult to accomplish, and can depend on complex impedances in your antenna and in the input to your receiver among other things. In other words, you can't easily compare "real" signal strengths in the ether between signals on widely separated frequencies. Nor do most of us need to; it's more than enough to know how deep a null is, or how much stronger one signal is than another. Even that would be a reasonable challenge for the homebrewer, if he wants to apply accurate decibel readings to such observations.

IF filters.....Here is a fine subject for argument, both in the type of filters to use, and in what IF frequency to use. Mechanical filters are available for 455 kHz while crystal filters are more widely available for the 9MHz range. The choice can be based on what sort of front-end the receiver has. It it has plenty of preselection, then there should be little image problems, even at the low end of the BCB, when using a 455 kHz IF. But if the front end is broadbanded, then a higher IF frequency (with a suitable low pass filter at the antenna) will be necessary to avoid image problems. Here, the 9 MHz filters and IF stages would be a better bet.

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It has been implied that the sharp passband edges of mechanical and some crystal filters might introduce distortion in the presence of transients (noise bursts and the like)--see p.227 of Solid State Design for the Radio Amateur. Some crystal filters apparently have "rounder" edges to the passband, as do ceramic ladder filters. Most ceramic filters don't have as narrow a bandwidth as desired by DXers, and their ultimate rejection is usually inferior to mechanical or crystal filters. If you're an expert in the subject, superior crystal filters with exactly the desired passband shape and frequency could be constructed, but most of us will have to stick with what's commercially available. Filter passband shapes have not really been investigated as far as MW DXing goes, beyond getting the best shape factor and ultimate rejection, so it's all virgin territory. My own primitive observations lead me to believe that the sharp edges between the top of the passband curve and its skirts, common to most quality IF filters, lead to increased interference when trying to dig a weak signal out from under sideband splatter from an adjacent signal.

The desireable passband for an IF filter is generally considered to be 2 to 4 kHz (at -6 dB down) for DXing purposes. Narrower than 2 kHz, and recovered audio in even a sideband mode becomes too muddy for good intelligibility. However, the narrow bandwidth does make for better receiver sensitivity and signal to noise ratio. Filters wider than 4 kHz generally don't improve intelligibility of a DX signal enough to compensate for the greater possibility of interference being contained within the passband. This is talking in terms of a weak DX signal a kilohertz or two from a much stronger signal. Domestic DX can be handled using filters with wider passbands than 4 kHz, and if possible, should be, for best intelligibility when using both sidebands of a signal.

The IF filter is usually placed in the signal path before any major amplification takes place, to minimize intermodulation distortion (IMD) from signals removed from the filter's passband. A little amplification is usually required before the filter, in order that the receiver's noise figure does not become too high due to the filter's loss. Of course, receiver noise figure at MW is not nearly as important as it is for higher bands; at the same time, one should not forget entirely about a receiver's noise figure. Ray Moore pointed out, in "Receiver Hot-Rodding Hints" in the NRC Receiver Reference Manual that it was not a good idea to cascade mechanical filters at the beginning of an IF strip, due to the increase in receiver noise level as well as the difficulties in isolating the output from the input in such a cascaded arrangement. The same idea would apply to crystal filters. However, placing a filter between each stage of the IF amplifier might be worthwhile for a couple of reasons. One is to eliminate out of passband IMD generated in each IF stage; the other is to improve ultimate rejection of the IF amplifier (the original purpose of cascaded filters). Radio amateurs have found that having a narrow filter at the beginning of the IF amplifier, and a slightly wider one between the end of the IF amplifier and the detector is worthwhile in that the second filter keeps most IMD and wideband noise generated by the IF amplifier out of the detector.

Another IF filter, which was quite popular in vacuum tube receivers, is the notch filter, which eliminates a narrow range of frequencies within the IF passband. Although interfering carriers can often be tuned out of the IF passband of a good receiver without much loss to the DX signal's readability (particularly if some form of synchronous detection is used), there are times when such tuning will move one closer to a signal rich in sideband splatter, and will generally increase interference. In such a case, it's preferable to use a notch filter to eliminate the offending carrier. Sometimes the level of a strong open carrier can be reduced by a notch enough to allow demodulation of signals underneath. At 455 kHz, a Q-multiplier notch is probably most useful, as a crystal based notch will not cover the whole IF passband usually. Up at 9 MHz, a crystal notch is much more feasible, while a Q-multiplier is not appropriate.

The mixer......We now look at the mixer, the portion of the receiver which must handle the strongest signals we throw at it, yet not produce obnoxious distortion products. A good deal of ink in the radio amateur press has been devoted to this subject, but one must remember that what may be a reasonable mixer for a radio amateur will not handle a clutch of 50 kw MW transmitters a mile away. So one wants a mixer with as good a strong signal handling capability as possible. The use of VMOSFETS in a double balanced configuration looks promising, but these circuits are still somewhat experimental, and consume a good deal of power. The availability of broadband double balanced diode mixer packages can simplify design considerably, and they are some of the most crunchproof mixers around. There is some loss in these mixers, but that's not really important at MW frequencies. They do require a healthy level of local oscillator injection, particularly the highest level mixers which suck in nearly ¼ watt of local oscillator power. Impedance matching is important at all ports of broadband mixers, so you have to know what you're doing--you can't just hang an antenna, an IF filter, and a local oscillator on such a mixer and expect it to work perfectly. The results can be well worth the work however, and there have been a number of broadband mixer circuits and theoretical articles in the radio amateur press to offer guidance.

The local oscillator.....A great deal of work goes into designing the local oscillator of general coverage receivers because the circuit must cover a wide frequency range with reasonable stability. The problem is simplified considerably if you're concentrating on just one band of frequencies, however, and a stable L.O. for MW frequencies (using a 455 kHz IF) can be constructed with a minimum of components as long as care is shown in the physical layout and quality of the L.O. components, and in good regulation of the power supply for the L.O. Broadband amplifiers to bring the L.O. level up to that needed for the mixer are also fairly easy to construct.

A synthesized oscillator could be useful with higher IF frequencies if stability is desired, but at present a good deal of work would be involved in getting one going satisfactorily. Free running L.O.'s for IF's of 9 MHz can still be pretty stable if designed and built carefully. "Spectral purity" is needed in a L.O. in a high performance receiver, i.e. there should be minimal noise sidebands to the L.O. signal. It is quite difficult to measure this quality without high grade lab equipment however. Simple L.O. circuits using very high Q resonating elements seem to be the best ways to avoid excessive noise sidebands; see the discussion on pp.125-7 of Solid State Design.

Digital readout is driven from the L.O. and with many displays available now, there should be no problem with getting readout to .1 kHz if desired, but watch out for digital circuit noise being transmitted to a nearby loop antenna.

The front end.....It would be nice to report that one can hook up an antenna to a good broadband mixer and, without any preselection, get spurious-free reception. If the signal developed by the antenna is low level and the mixer quite a high level one, spurious-free reception is a possibility. Use of a high-Q loop may provide enough preselection to make a good mixer run clean, but untuned antennas may well require a couple of high Q tuned circuits before the mixer, particularly when listening near strong locals. Passive preselection by tuned circuits can get quite complex, as you want the circuits to be high Q, yet track easily with each other, and you don't want them to introduce too much loss before the mixer. Even at MW, some sensitivity is desireable! Joe Worcester's ideas on preselection (see IRCA reprint M3, "The Worcester Long Distance MW Receiver") could be looked into.

Unfortunately, use of high Q circuits for preselection might present problems when tuning up very close to a strong signal. At the desired signal's frequency, your high Q preselector will present a nice pre-determined resistive impedance to the mixer's input port. At the interfering signal's frequency however, that same preselector is (due to the nature of tuned circuits) going to present a complex impedance entirely unsuitable for the mixer input, with all the possibilities for IMD which that will present. So the strong interfering signal is going to have to be greatly attenuated by the preselector. Perhaps using a broadbanded, crunchproof RF amplifier (otherwise unnecessary for MW) and a brace of lossy tuned circuits and resistive attenuator might solve the problem, but at a great price in complexity. Of course, this assumes that you're building a super receiver in order to tune very close to your locals and get DX. If you're willing to allow a 10 kHz no man's land around your locals, the problem will not be nearly as acute. It's always a good idea to try for simplicity as well as best performance; the more complex a circuit becomes, the more opportunity there is for it to do something unexpected and unwanted (cf. Murphy's Law).

The future.....It still would be nice to use a broadband antenna with a broadband mixer, and not have to twiddle a batch of knobs for every new DX channel--or design some extraordinary tracking for a multitude of tuned circuits. Use of the highest level mixer one can afford will certainly help toward this goal; just add only the preselection necessary. However, IF filters themselves are the next weak spot of a receiver. Your mixer may have a dynamic range of 110 dB, but mechanical filters have a range of less than 100 dB; good crystal filters somewhat more. So the filters can generate IMD as well as the mixer. Also, there have been suggested interference rejection schemes which require the interfering signal as well as the desired signal to be passed on to the detector where the interference is defeated (e.g. "Eliminating adjacent channel interference", P.L. Taylor; Wireless World, July 1977). But this means more than an extra wide passband; the interfering signal's internal phase relationships should be shifted as little as possible, and our usual IF filters tend to shift phase relationships. Does it seem too far-fetched that the ultimate MW receiver in the year 2000 will be broadbanded at the front end (front end preselection also shifts phase relationships in the received and interfering signal), with a very wide IF passband? It would run against the accepted wisdom of today, but who knows what circuits will be developed tomorrow?

Further reading and acknowledgement.....The receiver sections of Solid State Design for the Radio Amateur, by Hayward and DeMaw, and RF Communications Data for Engineers and Technicians by DeMaw, give a great deal of information that I would only be able to repeat, so it's well worth looking into these two books.

Special thanks to E.H. Grossman for his help and ideas in the preparation of this article.

--NHP