A HIGH-SPEED RF MODEM

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Introduction:

Although the present 1200 baud Bell 202 standard is perfectly acceptable for normal packet-radio QSOs, the amateur radio community needs to be able to communicate at higher baud-rates if an inter-city trunk line, or backbone network, is ever to be implemented.

Many believe that the next generation of modems should operate at a minimum of 9,600 bauds. Steve Goode K9NG was able to successfully modify the Hamtronics FM-5 to operate at 9.6KBd (1) while another approach, that of Gary Field WA1GRC, is mentioned in the 1986 edition of the ARRL Handbook (page 19.37). From what the authors have seen of Gary's design (2), his approach appears very promising.

Motorola too has long been involved in the field of RF modems (see for instance ref.3) and has recently filed a petition with the FCC to allow for the creation of "radio frequency local area networks"(4). (The above list is by no means exhaustive and simply represents some of the designs with which the authors are familiar.)

This paper will describe the approach followed by several members of the Amateur Radio Research and Development Corporation (AMRAD) to design a high-speed RF modem. Another paper, presented to this Conference in the form of an Application Note, describes the actual circuitry used to generate phase-coherent FSK.

Guidelines:

This modem is intended for the radio amateur community and as such, from the start of the project, the design criteria have included:

- ease of duplication,
- use of readily available parts and
- minimum of adjustments to be carried out with only simple test equipment.

It is intended that the final design will operate at up to 56Kbd on 220MHz and 440MHz. This paper describes an interim version already operating in a breadboard configuration.

The RF Modulator:

Fig.1 shows the method employed to generate phase-coherent FSK. (The use of two frequencies not phase-related would introduce unacceptable splatter.) A 2.2MHz crystal-controlled master oscillator drives a dual-modulus counter. The RS-232 level data input (TXD) is translated to TTL and used to change the dividing ratio of the counter and thus generates two phase-related discrete frequencies, in our example 200KHz and 220KHz. This is in fact equivalent to having a 210KHz carrier shifting + and - 10KHz. (Should an 40KHz total shift be desired for higher baud rates one could use a 4.4MHz crystal in a similar set-up. The result would be a 420KHz carrier shifted + and -20KHz.)

A gate, when enabled by the RTS line, then feeds the output of the dual-modulus divider to a doubly balanced mixer. The output of the mixer is a 10.7MHz IF which is then heterodyned with a 210MHz local oscillator in another doubly balanced mixer to produce an RF signal in the 220MHz band.

The Demodulator:

Figure 2 shows the receiver portion, consisting of a low-noise 220MHz stage followed by a doubly balanced mixer where the local oscillator frequency (210MHz) is injected. The resulting IF output at 10.7MHz drives, via a trifilar- wound transformer (Mini-Circuits PSC2), two identical doubly balanced mixers (MC1496). Both have ceramic resonators output circuits tuned to 455KHz, but one has a local oscillator injection at 10.255KHz whereas the other has a L.O. of 10.235KHz. Thus when the IF output is 10.710MHz (mark), the doubly balanced mixer with the 10.255KHz L.O. produces an output at 455KHz and conversely, when the IF swings to 10.690 MHz (space), it is the other doubly balanced mixer which produces a 455KHz output. In the scheme just described, there are 8 major heterodyne products:

10,710KHz	-	10,255KHz	=	455KHz
10,690	-	10,235	=	455
10,710	-	10,235	=	475
10,690	-	10,255	=	435
10,710	+	10,255	=	20,965
10,690	+	10,255	=	20,945
10,710	+	10,235	=	20,945
10,690	+	10,235	=	20,925

Note that only the first two combinations can produce an output from one of the two 455KHz stages. The other heterodyne products fall outside the 455KHz bandpass and are eliminated.

The two outputs are then detected and fed to a comparator,the output of which is RXD. It is to be noted that no tuning is needed in the process.

The Synthesizer:

For the sake of clarity, figures 1 and 2 have shown the local oscillators as being crystal controlled. In fact, the unit uses a master crystal oscillator (at 2.2MHz in this particular case) whilst all other oscillators are synthesized. The 2.2MHz crystal oscillator output (located in the RF modulator section, see fig.1) is fed to a divider by 440 to produce a 5KHz reference frequency. Presuming the stability of the crystal to be +/- 0.001% (easily achievable with an oven) the crystal oscillator output can drift from 2,199,978Hz to 2,200,022Hz. At the output of the divider by 440, the 5KHz reference will thus drift between 4,999.95Hz and 5,000.05Hz, equivalent to a maximum drift of 0.1Hz.

All the local oscillators are designed along the following lines and thus only one will be described: the output of a 10.490MHz free-running voltage-controlled oscillator (VCO) is fed to an MC145151 divider-by-2,098 stage, thus producing approximately 5Khz. This output is compared to our reference 5KHz source in a phase comparator, the output of which is a variable DC voltage applied to the 10.490MHz VCO as negative feedback. Note that once phase-lock has been achieved, the output of the divide-by-2098 divider will drift in phase with, but no more than the 5KHz reference oscillator. Using the maximum drift calculated above, the 10.490MHz oscillator will only be able to drift 2098 x 0.1 Hz, or +/- 100Hz. All other oscillators phase-locked to this 5KHz reference will exhibit essentially the same stability.

An added advantage of this scheme is that the output of the RF modulator can be set to any discrete channel on 220MHz, and so, of course, can the receiver. It is thus possible to contemplate offsets for duplex operation, etc. Since the dividing ratio of each phase-locked loop is determined by a set of DIP-switches (the MC145151 can be preset to divide by any integer between 3 and

16383), changing the configuration of the equipment is an extremely easy task.

Conclusion:

The scheme described above is simple, easy to duplicate and only an oscilloscope and a frequency counter are needed to adjust the modem. It is anticipated that the major parts needed for this modem (including a printed circuit board) will be rnade available through a distributor.

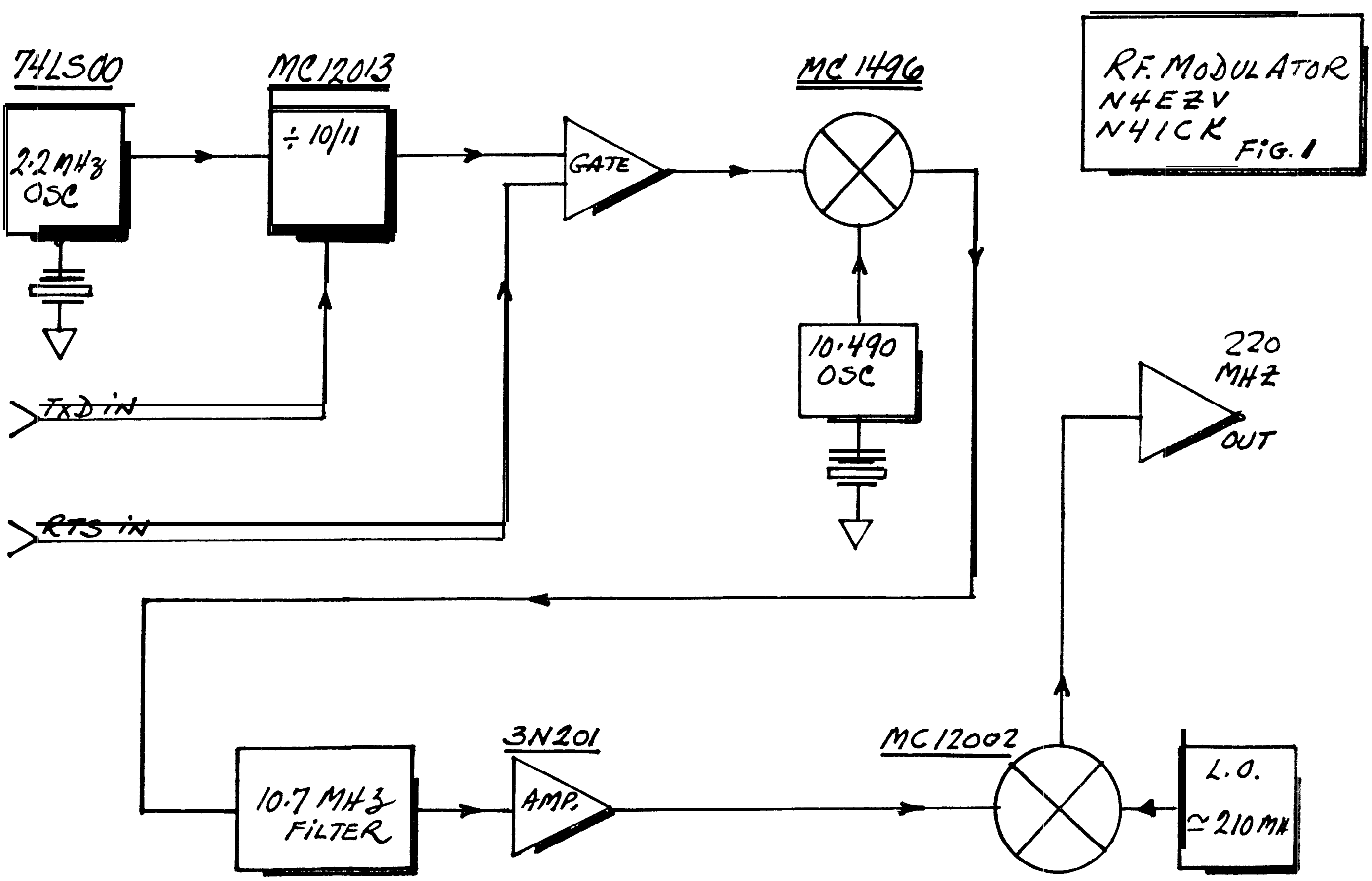
References:

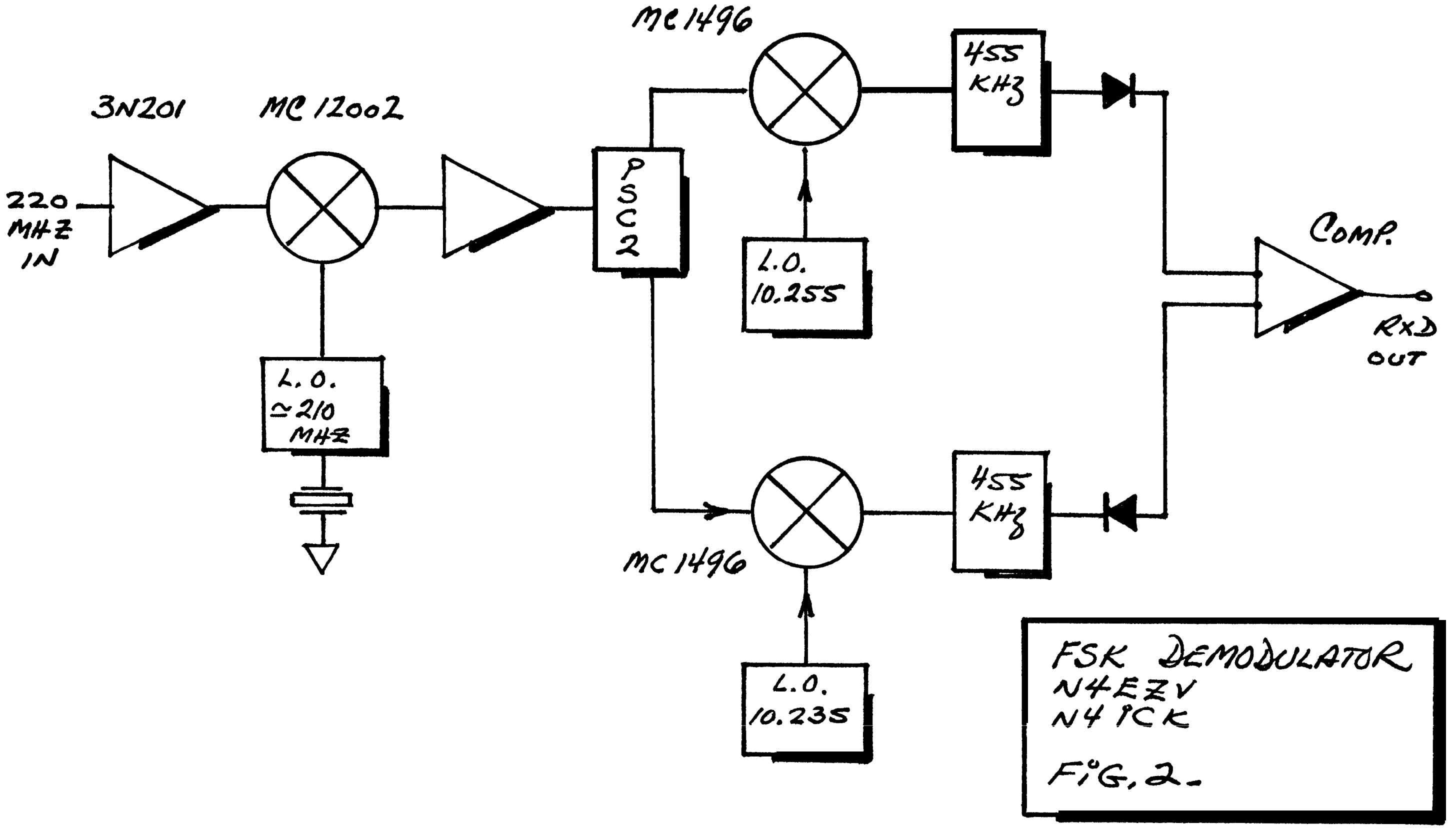
(1) GOODE Steve K9NG, "Modifying the Hamtronics FM-5 for 9600 bps Packet Operation." ARRL Computer Networking Conferences 1-4, pp 4.45-[illegible]

(2) Personal communication dated September 28, 1985.

(3) HATCHETT John and HOWELL Bill Motorola Semiconductors, Phoenix, AZ. "RF Modems", RF Design Magazine, Sept/Oct and Nov/Dec 1984.

(4) "Motorola Proposes Wireless Lan" Personal Communication Technology Magazine, Nov 1985 p.38




220 MHZ IN
3N201
MC 12002
L.O. ≃210 MHZ
PSC2
MC1496
L.O. 10.255
MC 1496
L.O. 10.235
455 KHz
455 KHz
COMP.
RxD OUT
FSK DEMODULATOR
N4EZV
N4ICK
FIG. 2.