RTTY

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NEWS OF AMATEUR RTTY

NOVEMBER, 1962
30 Cents
Vol. 10, No. 11

HORSE TRADES

This page of the Bulletin is for use of amateurs who have RTTY EQUIPMENT FOR SALE OR TRADE and those looking for equipment to buy or trade. It is a free service and may be the means of getting someone on the air.

WANTED: Purchase TM-11-2032 for Oa3/FC Reg. Rptr., V. A. Jupe, W0OKH, RFD 4, Box 12, Phillipsburg, Kansas.

FOR SALE: AN/FGC-1X TU complete with some spares and manual, $50.00. W6PZV, 1300 California Avenue, Compton, Calif.

TRADE: For Model 19 set, have model 15, model 26, 14FRX and FRA, TU. or cash. W6CQO, 309 Palomares, Ventura, California.

WANTED: Function can assembly with gear for model 26. K0MHB, P.O. Box 203, Reed Hall, N.D.S.U., Fargo, North Dakota.

FOR SALE: Model 14 typing reperf, cover, reel, rapid feed, end of line recv only base, sync motor, 60 wpm gears $75.00. Model 14 TD mounting base with connector $3.50. Polar relay socket $1.00. Reconditioned model 14 cover $17.00. Wanted model 19 keyboard with end-of-line indicator. K5AON, 867 Berkinshire, Dallas 18, Texas.

FOR SALE: Keyboards for model 15 $15.00 PP. Aluminum casting keyboards as above $17.00. W2ZKV, 84-24 57th Ave., Elmhurst, L.I., N.Y.

WANTED: Copy holder for either 14 or 15 cover. W7PQJ, P.O. Box 411, Lebanon, Oregon.

FOR SALE: Two model 15 machines, complete with tables, and pwr supplies. Keyboards, covers and cranks, perfect condition on both. One model 19 complete, printer, cover, keyboard, TD, table and power supply. Sending polar relay included, condx excellent. One URA-7 dual diversity TU complete. Connectors and cables, two CV-71 TUs and one CM-14 comparator in desk top rack. Condition new. One R-274/FRR receiver, .5 to 56 mcs in six bands. Same as SX-73 (military version). Condx, excellent. One W2PAT TU with 3" scope. W9PRX, 105 Durley Drive, Belleville, Ill.

FOR SALE: Model 15 with sync motor, table, pwer unit, 60 wpm, $110.00. RA-87 rectifier $12.00. Non waiver gear. W7EQU, East 318 Courtland Avenue, Spokane 22, Wash.

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GETTING STARTED ON RADIOTELETYPE

IV — FSK KEYING CONSIDERATIONS

By IRVING M. HOFF, K8DKC
1733 West Huron River Drive
Ann Arbor, Michigan

(Editor's Note: This is the fourth in a continuing series of articles designed to help the new-comer to understand and apply the basic principles of radioteletype.)

THE LOCAL LOOP POWER SUPPLY

Diagram A is a typical "local loop" power supply. The term "loop" refers to a continuous circuit. An average station has three "loops" — receive, transmit and local. Sometimes these are combined by using the first two alternately from the same supply.

Diagram A is particularly suited to 25 ma. requirements. (You will hear some fellows running "20 ma. loops"; some running 30 ma. and some running 60 ma. — we will use the term 25 ma. to be typical.) If you need to run 60 ma. in your printer, you might be interested in getting some heavy-duty filament transformers and running a pair "back-to-back" in order to have adequate current. Olson Radio of Akron, Ohio, sells an ideal transformer — their T-290. Priced at three for $4. One driving the other two will provide two loop supplies of 120 ma. each at 125 volts.

Newer type machines using holding magnets require 20-30 ma. with the magnets in series; 60 ma. in parallel. Older machines with pulling magnets use 60 ma. and the magnets are in series. The newer type usually have the letters "HM" stamped on the range lever plate that is marked with the 0-120 scale.

When in series, there is 180 ohms DC resistance across the selector magnets. With 25 ma. it would take 4½ volts to run the coil. However it takes a great deal more voltage to build this 25 ma. as rapidly as possible.

If a Corvette and a Volkswagen were parked at a traffic light which turns green, the high-powered car can obtain the legal 25 mph very rapidly, but the Volkswagen takes a little longer. Once at 25 mph, either car needs only a fraction of the power available to maintain this speed.

So it is with our printer — we want a big "kick" to start things going rapidly, and then can coast the rest of the pulse. So we use 100-150 volt power supplies, although this is reduced to the 4½ volt figure for the remainder of the pulse.

Only one local loop is needed in the average station, and will handle several items in series at once, including tape equipment.

FSK

This stands for "Frequency Shift Keying". In the early days of RTTY, only MAB (Make and break—like CW) could be used on the 80-10 meter bands. Since there are up to 43 pulses per second transmitted (at a steady 60 words per minute), the least little burst of static or interference would blur a great many pulses, causing a long string of errors. By shifting the transmitter frequency a small amount for each pulse, a definite means results for the converter to tell between a mark and a space.

The figure 850 cycles* was arrived at after much computation, and takes into consideration the pulse rate of 22½ milliseconds. We wish to transmit "square waves" in order to give optimum range for printing at the receiving station. Thus to reconstruct the square wave properly, allowance must be made for the third and fifth harmonics of 22½. We will just conclude with the fact that 850 was selected as being the optimum shift. There has been a great deal of experimentation with "narrow" shift FSK, but there is some question as to whether it would ever be as good as 850 for normal use, although it has certain inherent advantages such as using less band-space, offering greater protection from interfering signals, etc.

In any tuned circuit using an LC relationship, varying either the inductance or capacitance will vary the frequency of the circuit. Since it is much easier to change the capacitance, this is the type of circuit we shall disuss.

*Editor's note. 850 cps is somewhat arbitrary shift value used by commercial and military radioteletypes. Incidentally this is reason for use of 2125 mark and 2975 cps space, being the fifth and seventh harmonics of 425 cps, and such tone frequencies were chosen to obviate problems due to multipath and consequent generation of 850 cps and multiples in the audio circuitry. Many commercials are now running 425 cps and even 170 cps, such as NSS on around 7.4 mc, transmitting standard 60 wpm Baudot codes.

Placing a small condenser from the cathode of the Clapp VFO to ground will lower the frequency of the transmitter. This is the method we shall use for FSK. The normal frequency will become the "Mark" frequency and the altered frequency will be called "Space". Remember "LSMFT"—Low Space Means Fine Teletype. This would give a pitch on the receiver which would then be lowered in tone for space. So should you walk into an RTTY station which was "on the air", you would hear a 2125 mark tone, and a 2975 space tone. If he had a Single-Sideband type receiver, it would be on lower sideband.

There are actually several methods of adding FSK to a transmitter. We can shift the VFO, which is by far the most common; we can add AFSK to the microphone input of the transmitter (used on VHF, and sometimes on HF with SSB transmitters that remove the carrier and unwanted sideband so that "normal FSK" results), and we can shift crystal oscillators. This last type has never been utilized to a great extent and offers great potential for elderly AM/CW transmitters with "tired" VFO's.

Several transmitters are now using crystal shift including the 100-V; 200-V and the new Heath-kit "Marauder" HX-10. The integral crystal-shift of the Hallicrafters HT-32A and HT-32B was not successful and is not used for RTTY. Additional information on Crystal-FSK will be given in a later article.

THE BASIC KEYER

Diagram B illustrates the basic keyer that will be incorporated into the VFO area. All other types of keyers are variations of this basic circuit.

In past years before the development of the crystal diode, it was customary to use a 6AL5 tube to switch the small condenser in and out as desired. Now we normally use a crystal diode as they are so much easier to use and do an excellent job.

At radio frequencies, a diode looks like a resistance in series with a capacitance. With no voltage on the diode, it is the equivailent of about ½ mmfd. The resistance is on the order of one megohm. With enough current to saturate the diode (several ma.), the resistance changes to a very low value, and the capacitance goes up to 10-20 mmfd. Diagram C shows how the frequency will vary with respect to a change in voltage applied to points *X* and *Y* of Diagram B. You will see that the current stays nearly the same:

1.6 ma. at 50 cps
2.6 ma. at 900 cps

A most interesting thing occurs when *X* and *Y* are shorted together — depending on the setting of the trimmer, a sizable shift in frequency will occur. In fact, 850 cps shift can be easily achieved. At that time, only 0.06 volts is generated, and some 300 microamps current. This is actually a little like the self-generating crystal detector once used in the famous "crystal sets" for receiving. In this case, the diode actually rectifies a little RF, and when the points *X* and *Y* are shorted, provides a DC path to ground. It is this phenomena which causes our headaches to start. Up to this point about 5-6 mmfd is all that is necessary to reach 850 cps shift. Adding the keyer to the transmitter has caused only perhaps a 100 cycle shift from the ordinary dial setting.

This could be keyed on and off with the keyboard and excellent results could be obtained. Just one small problem — it is "upside down". We shall shortly show how to get normal FSK from this type of circuit.

Look again at Diagram C. If we vary the voltage, we can change the shift. Look at the 900 cycle area — further increasing the voltage 0.5 volts has little affect on the shift. If no intentional shift were desired, we could then set the voytage to this much or more, and set the trimmer to 850. Then variation of the voltage would produce little or no change in frequency.

These two systems, then, are the basic ones in use today for FSK — we shall call them "controlled-voltage", and "saturated diode" systems. Each has certain characteristics that we should consider. In general, the controlled-voltage method will be easier to use for AM/CW transmitters involving multipliers for different bands, and the saturated diode will be preferred for SSB transmitters. If a heterodyne VFO is used for an AM transmitter, use the saturated diode — if no multiplication of frequencies are involved in any way — (The Hallicrafters HA-5 VFO requires multiplication for 20, 15 and 10 meters, etc.)

FSK FOR AM/CW TRANSMITTERS

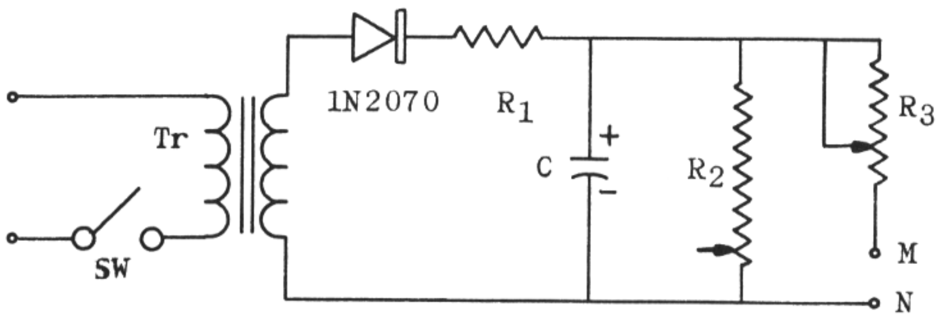
The normal VFO has two basic ranges: one for 160 and 80 meters; and one for 40 meters. This latter doubles for twenty; triples for fifteen, etc. (and multiples any drift problem at the same rate!)

Thus we need a method of conveniently changing the shift — otherwise the 850 cycle shift set for 40m would become 1700 cps on 20m and 2550 on 15m, etc.

An "ideal method" would be to install the trimmer condenser in such a manner that it could easily be changed from the front panel with an additional knob. However, few will be willing to ruin the resale value by this method. So we use the "shift-potentiometer" which will vary the voltage, and can be located at a convenient remote position.

Diagram C shows that we need never have more than 0.5 volts at points *X* and *Y* (for a 1N270). It also shows that any small

LOCAL LOOP POWER SUPPLY



SW	SPST	$0.60
Tr	Stancor PA-8421	3.84
C	60 MFD. 250 WVDC	1.46
R_1	68 OHMS 2W	0.48
R_2	25K 25W Adjustable	1.61
R_3	7500 OHM 25W (25 ma. loop) (Use 2500 ohm 60 ma.)	1.42
	1N2070	1.35
	Total	$10.76

DIAGRAM A.

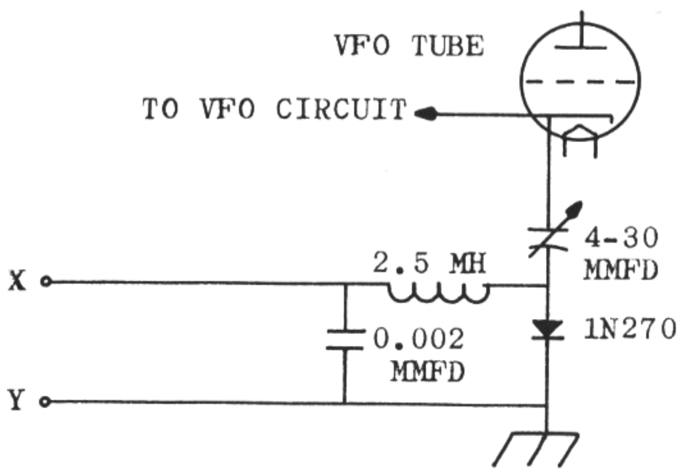


DIAGRAM B.

variation in the voltage can cause a frequency change!

So we use regulated voltage, and reduce it to the 0.5 volts needed. Most AM transmitters run 150 volts regulated to the screens; plate of the VFO, etc.

Figure 1 shows how we get the voltage to drive the diode. Most of the 150 volts is dropped through the large resistor, and about 0.5 is remaining with the pot open.

Figure 2 shows how we key this for transmission – the keyboard is normally closed, and provides a path to ground for the voltage normally coming from the pot. When the keyboard is open (space), the voltage conducts through the diode, and FSK results.

In figure 2, the keyboard contacts are never at more than 0.6 volts. This is not particularly good, as they should have some operating voltage across them in order to keep oil films from building up and adding distortion to the signal.

Figure three shows how to overcome this – The keyboard contacts now operate at about 30 volts DC.

So add figure 3 to Diagram B, and you have it.

We stated a bit ago that when *X* and *Y* are shorted out, a self-rectifying action takes place. Since we now must short *X* and *Y* for normal mark operation, this will cause the frequency to shift somewhat, before we even go to space. As we set the trimmer for 850 cycles, this mark will shift some also. By the time you get 850 cycles shift set, mark may now be some 5-6 kilocycles from the original VFO setting. This can be overcome with reverse bias on the diode, but that is an advanced type of circuit that we will leave for later in this series. Also narrow shift CW Identification can be added, but again that takes some explanation which is not pertinent at this time. Because the mark frequency moves several kc from normal when using this circuit, a quite large trimmer must be used. If the 4-30 illustrated will not give at least 850 cycles with the pot open, either replace it with a 7-45 or 8-50; or else put a small non-drift fixed condenser of 10 mmfd in parallel with the trimmer.

FSK FOR SSB TRANSMITTERS

(Also for AM/CW transmitters where only one band is used; and AM/CW transmitters using heteordyning types of VFO's.)

Some SSB transmitters have crystal mixing stages that require reverse operation on one or two bands. The Hallicrafters series is an excellent example. Eighty and forty are backwards from 10, 15 and 20 meters.

Also the VFO has a basic range that does not change from band-to-band. Thus once we set the FSK for 850 cycles, there is no need to again change the setting. (Actually there will be a slight change in FSK from one end of the VFO to the other, but this change can be ignored for practical purposes.)

Thus we can now eliminate the requirement for a shift pot and instead concentrate on a system where small (or even large) variations in voltage will produce no undesirable effect.

By saturating the diode well beyond full conduction, we no longer need regulated voltage. Since we see from Diagram C that full saturation occurs at about 0.5 volt (which was actually 2.6 ma.) if we were to run 5-10 ma., then a change of 50% in the voltage at point *X* and *Y* would produce no effect on the shift. We can now use the local loop power supply to provide this voltage. We can also now use the keyboard in series with the printer magnets, and no longer need to rely on the converter to run the printer while transmitting. This of course is much more convenient and allows for cross-band operation, etc. (As on Armed Forces day when NSS transmits to the amateurs on Navy frequencies and listens on amateur frequencies.) It also allows for rapid break-in where the other station has drifted off your frequency and you decide to stay where you were.

It also allows for reverse bias to be easily added, which enables you to use a small trimmer condenser, and that the same time the frequency for mark will be only 100 cycles or so from the original dial marking on the VFO.

At the same time, you no longer rely on the decay time of the diode to form the rear slope of the transmitted pulse, but force the diode to conduct and stop conducting with reverse bias. This enhances the printing range at the receiving station. The circuit also readily adapts to narrow shift CW Identification.

In figure 4, the keyboard and magnets are in series at M and N. During mark there will be a voltage drop of about 25 volts across the 1K resistor (25 ma. loop) R1 merely maintains the loop current at 25 ma. During space, the circuit is open and there will be no voltage across R2. Point N will then change from plus 25 volts to zero.

In figure 5 we have added the bleeder resistor from Diagram A. If tap C is set for 12½ volts, this will stay constant regardless of mark or space condition.

We now have the situation where point *X* will always be at plus 12.5 volts while point *Y* will then be plus with respect to *X* for mark and negative for space. This gives our reverse bias cut-off for mark and conduction for space.

When the Diagram B is hooked to this circuit, it would be best to readjust tap C so that for conduction 5-10 ma. result. Since point *Y* will go from zero to plus 25 volts, we must add an isolating condenser to Diagram B so the local loop power supply will not be grounded during mark — it won't blow any fuses, but would not provide reverse bias cut-off.

Another convenient feature in this circuit is that it makes no difference if the diode is inadvertently installed incorrectly. Just reverse the leads at *X* and *Y*!

Figure 6, then is the completed circuit, using the last half of diagram A. By carefully installing the trimmer condenser properly, screwdriver adjustment can be made during conduction without using special insulated tools. Make sure the part the screwdriver touches is hooked to the diode and not to the cathode. Figure 6 includes a reverse switch for those transmitters needing one. If you intend to later add narrow shift CW ID, get a CRL 4-pole two position non-shorting switch type PA-1458 for $1.44.

SUMMARY

The 1N270 was used here for illustration. It is a gold-bonded low impedance fast-switching computer diode, costing 50¢. Many other types will work as well — the 1N34A; 1N38A; 1N100; 1N297, etc. all do a good job, but might require a somewhat different resistor than the ones in figures 2 and 3. For figure 6, no corrections would be needed, but a check should be made to assure that 5-10 ma. resulted during conduction.

With figure 6, any reasonable number of machines may be used in series for transmission at the same time.

Other circuits may be worked out if desired from these two basic types.

Next month we discuss the converter for receiving the signal.

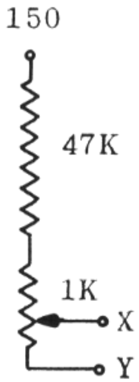


Fig. 1

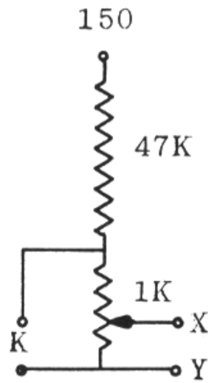


Fig. 2

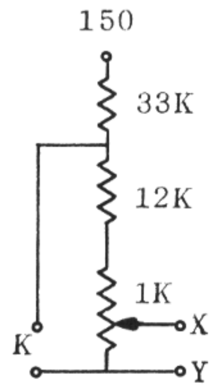


Fig. 3

(It would be best if all resistors were wire wound to minimize shift change due to heat)

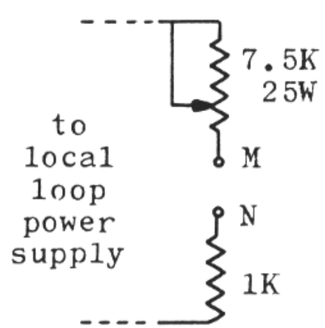


Fig. 4

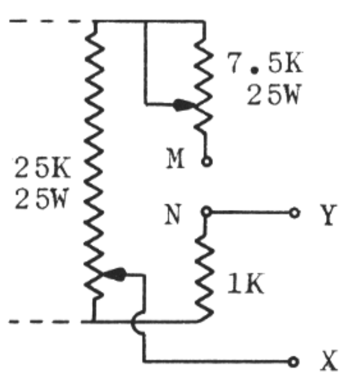


Fig. 5

FSK USING CONTROLLED-VOLTAGE (1N270)

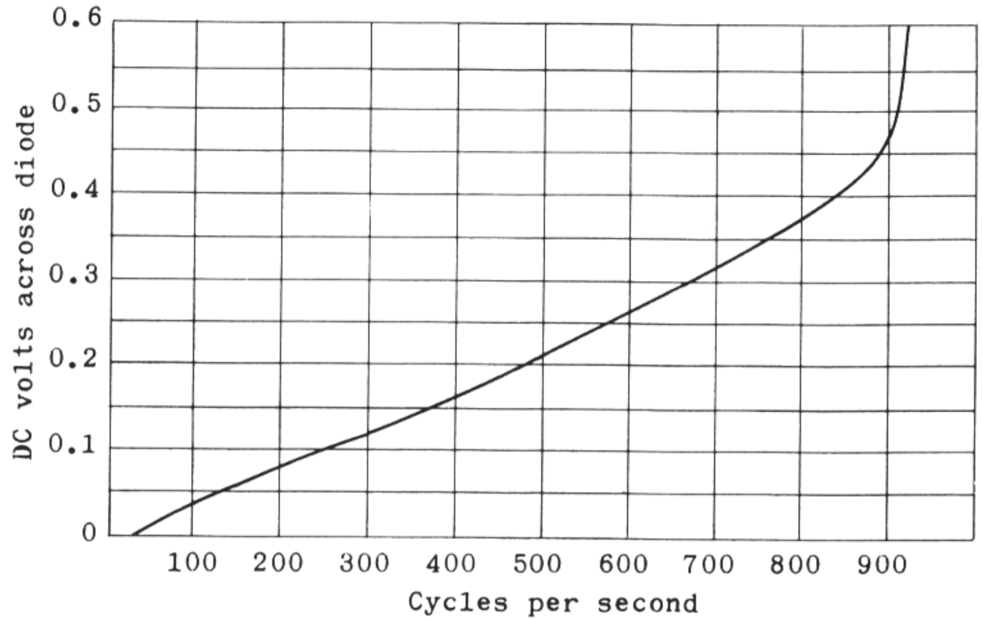
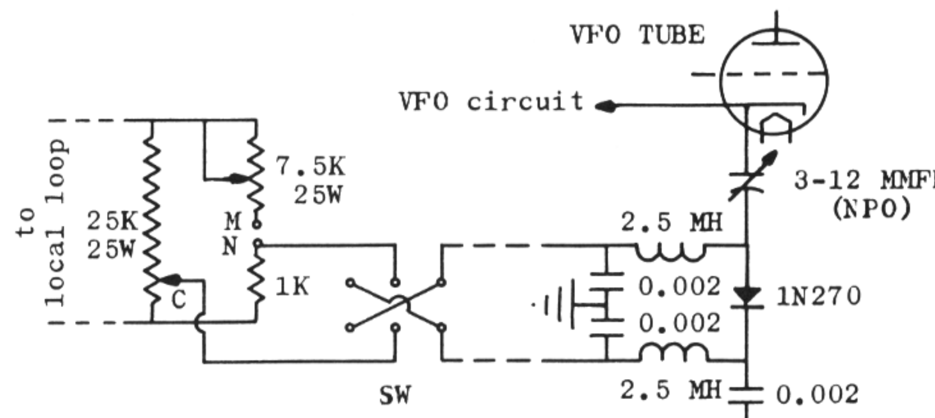


DIAGRAM C.



SW--use a Centralab PA-1458 so you can later add narrow shift CW ID

Fig. 6

"NEW HORIZONS IN AMATEUR HF-RTTY TRANSMISSION"

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Edwards AFB, Calif.

1. Amateur radio has a proud history of pioneering communication techniques. RTTY'ers particularly claim this heritage because of the tradition, "RTTY'ers BUILD." This paper is intended to bring to your attention some of the new communication techniques related to RTTY which seem amenable to amateur experimentation. With the hope of stimulating experimentation and avoiding some erroneous statements, the writer has deliberately left questions unanswered, omitted data, and failed to draw conclusions. Or, to borrow a familiar phrase from the textbooks, "the demonstration and proof is left as an exercise for the reader."

2. The superiority of FSK over make and break (AM) transmission for RTTY has long been known[59]. (This assertion is made only for the means used to transmit on-off information, and does not take into account the nature of the instruments used for transmission and reception.) The reason for this superiority might be inferred from either of two arguments.

a. FSK is a form of FM. The bandwidth of the composite FSK signal is considerably greater than the bandwidth of the comparable AM signal. Therefore it is possible to effect a trade-off with this increased bandwidth to obtain a signal-to-noise-ratio advantage.

b. The composite FSK signal may be viewed as a diversity pair of AM signals, provided the shift is sufficiently large. Thus the usual diversity improvement occurs. Further, if the system operates under a peak power limitation, the diversity system as compared to the single AM system is able to transmit a higher average power.

3. It can be shown that the existence of these two considerations is basically a difference of concept rather than a real difference between two kinds of signals. For instance, the usual diode modulator/VFO FSK transmitter generates essentially a true FM signal. A wide-shift FSK signal might also be generated by switching between two oscillators which differ in frequency by the desired amount of shift. There is practically no difference between the signals generated by either process if ordinary transmission channels and detectors are assumed to be in use. This similiarity ceases to exist, of course, for small values of shift; for a round figure, when the shift is less than 10 times the fundamental keying frequency.

4. This difference in concept does affect the design of receiving equipment. In theory the FM concept leads directly to the limiter-discriminator type of receiver, while the AM concept suggests the two-filter receiver approach. In practice the distinction between the two receiver types is rather blurred, because of the almost universal use of limiters and because of the far-from-ideal characteristics of simple channel filters.

5. Beyond this point, involving the construction of much equipment of both types, amateurs seem to have done little of late to improve transmission capibilities. Only recently has narrow shift again become an acive subject. There has been but little recent theoretical work on improving receiving equipment even for standard-shift signals.

6. Consider now a typical system composed of 60 wpm TTY equipment, a diode-modulated/VFO transmitter, and a limiter-discriminator signal converter such as W6NRM's III. Such a system is perhaps a little better than the average amateur RTTY installation and is conveniently chosen as a standard of comparison for further discussion. This system assumes the FM concept for the FSK signal.

7. A characteristic of such systems is the existence of an *improvement threshold*[31], as illustrated by the following figure:

Qualitative performance curve for typical FM system.

Thresholds exist iny many systems and may be defined in various ways. In seeking to improve systems, we may have either or both of two objectives:

a. reduce the error rate for signal/noise values which are above the threshold.

b. reduce the value of signal/noise at which the threshold exists.

8. We might expect, intuitively, that for our typical RTTY system a threshold exists where the peak signal voltage is equal to the peak noise voltage. This situation is inferred from the consideration if limiter capture. Unless we know a great deal about the noise we cannot express the threshold condition terms of signal/noise as measured on an average-power-reading device.

9. In practice, then, we cannot state an exactly predicted threshold for our typical system, but we can make measurements which will reveal its location. We can infer from the above intuitive consideration that the typical system does have a definite threshold which limits our ability to improve the system. We can seek to improve the typical system in those environments where peak signal always exceeds peak noise. If the reverse is true, we can attempt to bring peak signal above peak noise by prelimiter filtering. That failing, we must discard the simple limiter entirely and seek better detection methods.

10. While the subject of noise is extensive in itself, we amateurs are concerned mainly with:

a. narrow band noise, such as QRM from Morse stations, phone carriers, etc.

b. wideband noise such as hiss, jamming, power leak, and modulation splatter.

c. spike-type noise such as switching transients and motor noise

d. flat fading, in which all frequencies of interest fade together

e. selective fading, in which path loss is high at only one, varying, frequency

f. multipath interference

11. we will consider first the case in which the signal is below the system threshold; that is, when peak signal is less than peak noise. In the standard system narrow band noise is treated in two steps. First the transmitter frequency (of the desired signal) must be adjusted until the frequency of the interference is not too close to the signal frequency. Then a filter is used which attenuates the noise more than the signal, the difference being great enough to bring the signal above the threshold. If we can obtain these two conditions, the capture effect will act to suppress the noise, so that a net improvement in SNR results from passing the signal through the limiter. If the second condition cannot be met, so that the signal remains below threshold SNR then the limiter will act to make the SNR at its output even worse than that it its input. If the first condition cannot be met, the filter never gets a chance to do its job, so that the second condition cannot be met, either.

12. Assume, for the sake of further discussion, a fairly typical set of conditions: there exist interfering signals stronger than the desired signal, but the band is not so crowded that the desired signal cannot be moved out from under the interference. With these conditions the limiter-discriminator receiver has a fair chance to produce an acceptable output. The first problem is the design of an input filter.

13. Amateur RTTY receivers have been undergoing a slow evolution. Most of the early converts had limiters which were not preceded by input filters; the radio receiver selectivity, which was poor, was the only bandwidth restriction in the system. Receivers of that vintage offered a choice between either a very broad "phone" selectivity or a very narrow "C.W." crystal-filter selectivity. The single-crystal filters were entirely too peaked for wide-shift FSK reception; the phone selectivity was typically 8 kc. This gave the radio receiver an audio response to the audio image (signals on the oposite side of the BFO frequency from the desired signal). Soon it was realized that a bandpass filter, connected ahead of the limiter, could do wonders for the situation. A typical filter of the period had the characteristics shown in Figure 2.

14. Such filters were occasionally aided by tunable notice filters. These were used to remove interfering signals which were not sufficiently attenuated by the poor skirt selectivity of the simple bandpass filters. In a considerably better position were those who used 1.1kc mechanical filters in their radio receivers. These filters offer a much better skirt selectivity than the simple pi-section bandpass filter. We can, however, do somewhat better than either.

15. It can be shown, with the aid of some mathematics too abstruse for this writer to follow, that the ideal input-system filter should match the spectrum of the desired signal[5]. Consider now the situation of an RF oscillator frequency shifter at a 23 cps rate, which approximates 60 speed RTTY transmission. The transmitter output will look something like this:

16. f_c is the center frequency, which is usually disregarded in amateur work, f_m and f_s are the marking and spacing frequencies, and are separated from f_c by 425 cps in each direction. The sidebands are all spaced from f_c by integral multiple of 23 cps; since 425 is not an integral multiple of 23 there will be no sidebands at exactly f_m and f_s. The largest amplitude sidebands, which will be called the principal sidebands, will be very near f_m and f_s[3,13,16].

17. We can, in theory, match a filter to this spectrum exactly by tuning very narrow bandpass filters to each of the sidebands and then combining all of the outputs of these filters. Since the sideband frequencies are as precise as f_c and the modulating frequency, we can make these bandpass filters almost as narrow as we please, and thereby exclude a lot of noise. Unfortunately the end result of this design is a system which will transmit a 23 cps square wave and absolutely nothing else. About the best that can be done in practical amateur work is to construct a filter which matches the envelope

of the signal spectrum; that is, a filter with a response something like this:

A few such filters have been designed and used in amateur work. They are often called comb filters. A couple of intuitive observations suggest how they work.

(1) Regardless of the actual intelligence being transmitted, the envelope of the 23 cps-modulating frequency spectrum will match the envelope of the actual transmitter output rather well even if the sidebands don't have the same frequencies in the two cases (of FSK viewed as AM or as FM). The peaks must occur quite close to f_s and f_m since the transmitter instantaneous frequency is at one of these frequencies most of the time. Similarly the transmitter frequency spends little time in the vicinity of f_c; there is therefore little energy transmitted in this portion of the spectrum.

(2) Since the vicinity of f_c is relatively unimportant to the signal, the function of the filter is to desensitize the limiter to interference in this region of the spectrum.

18. The consideration of the signal spectrum brings out another point. Although the signal peaks may be 850 cps apart, it is not true that the bandwidth of the signal is greater than 850 cps. The actual bandwidth in terms of spectrum occupied is quite a bit less, perhaps 200 cps or so. Thus 850 cycle shift at 60 speed is not highly effective in achieving the FM objective of trading bandwidth for signal-to-noise ratio. Note the common commercial practice of interleaving two 850 cycle shift signals so that f_m of one signal falls at f_c of the other.

19. This observation suggests other approaches to the filter matching problem. First of all, shift might be narrow until the hole in the spectrum around f_c is filled in. The following figure illustrates several spectra for comparison.

Note how the lower spectra approach closely the response curves of simple filters. Thus narrow shift is one way to achieve better reception through better filter matching. Note, too, that according to the filter matching concept, the "ideal" bandpass filter having a flat top and steep skirts is not ideal at all.

20. A second approach is to modify the modulating signal spectrum so that it contains a more uniform energy distribution: one more suited to the response of simple filters. We might, for example, connect a low pass filter (with a cut off frequency of perhaps 30 cps) between the TTY circuit and a linear frequency shifter.

Such a filter would convert the nearly rectangular TTY waveform into an almost-sinusoidal form. The resulting signal spectrum in this case would be highly dependent on the modulation index; but the general tendency would be toward the production of a smaller number of more evenly distributed sidebands[15]. Indeed we can expect a more uniform energy distribution from a consideration of the amount of power transmitted at each instantaneous frequency. Instead of a filter we might use an integrator, producing a triangular waveform. This would generate a peculiarly difficult waveform to handle in a transmitter since the frequency deviation would depend on the previous history of the waveform. It might be made more tractable by limiting after integration. In any event, the aim of these signal shaping techniques is to transform the sharply-peaked normal FSK energy distribution into a more uniform one which is thus easier to fit with a filter and which makes a better use of the total bandwidth occupied by the signal. Note that these signal shaping techniques require high transmitter linearity (even-harmonic distortion would be particularly deleterious) and some means of "unshaping" at the receiver to restore the original rectangular waveform.

21. The exhaustive discussion of filtering has led us rather far away from the topic of limiting. Before returning to the latter subject, let us note that many of these filtering concepts are even more useful in systems which do not use limiters.

22. Theoretically a limiter improves S/N when peak signal exceeds peak noise, and degrades S/N when the reverse is true. We use prelimiter filtering in an effort to maintain the desirable state of affairs. Assuming that we succeed in this worthy aim, we become concerned with how well the limiter performs its job. Ordinary limiters are so commonly used that it is not necessary to discuss them here. Some discussions of cascaded limiters will be worthwhile however.

23. A limiter circuit containing no input or output filtering might be called a wideband limiter. Similarly, a limiter circuit with an input bandpass filter can be called a narrowband limiter[32]. Cascading wideband limiter stages is of little importance for signal enhancement; this technique is used simply because the dynamic range of the usual limiter is insufficient to handle signal level variations that may be encountered. Cascading narrow band limiters has possibilities which are considerably more interesting.

24. It is intuitively obvious that the output of a limiter contains frequencies which were not present at the input. Not so obvious but more important is the source of these added frequencies and their relations to the limiter input signal frequencies. Consider a limiter with two simple-frequency input signals. One of these, the stronger, represents a desired signal, while the other represents noise. If the desired signal is actually frequency modulated, we resort to the method of Baghdady[31], assuming that the modulation is slow compared to the other processes which are of interest at the moment and which involve frequencies in the neighborhood of the difference between signal and noise frequencies.

With this assumption, the principal frequencies at the limiter output are the signal frequencies, their harmonics, and the intermodulation products of these frequencies. Since we are interested in interference frequencis which are near the signal frequencies (but sufficiently far removed that the stationary-modulation assumption holds), we may neglect the harmonics and higher frequency intermodulation products. In the frequency domain we find that there are now signals present at the signal and noise frequencies and at multiples of the difference frequency from the signal frequency. In the time domain, the instantaneous frequency goes through wild gyrations extending over several times the difference frequency, but averages to the frequency of the desired signal. It seems that if this mess is passed through a bandpass filter similar to that at the limiter input, the signal emerges somewhat less perturbed by the noise and the variations of instantaneous frequency are considerably reduced. It is as though the filter were so sluggish[31] as to be unable to change frequency at the rate demanded by the input. In the frequency domain, the effect of the filter is to attenuate the noise with respect to the signal, so as to improve S/N. With this happy result, another limiter stage following the second filter has a much better signal to work on, so that it, too, improves S/N even further. Thus it is seen that cascaded narrow-band limiters can effect a greater improvement in S/N than can a single limiter. This scheme has been used in actual practice; but cost and other factors place a limit on the number of limiters that can be used in cascade in an actual system.

25. The ingenious Mr. Baghdady has provided a technique which in amateur lingo might be called a "limiter multiplier"[33]. This circuit consists of a narrowband limiter followed by a bandpass filter similar to the input filter. The output of this filter is reintroduced into the input filter, in-phase, so as to achieve positive feedback. The net result is the same as though several cascaded limiters were in use. The operation may be visualized as follows. If the input signal is stronger than the noise, an improvement in S/N results from the limiting and filtering. This improved signal adds in-phase to the input signal, so that the closed-loop limiter input has a higher S/N than the original signal. This better signal is further improved by the limiter action, and so on. Greatest sensitivity is achieved if the gain around the loop is sufficient to produce oscillation in the absence of an input signal. With an input signal, the frequency of this oscillation is forced to follow the frequency of the signal.

Experiments with this system at M.I.T., using an operating frequency in the megacycle range, demonstrated almost complete suppression of interference even with the input S/N very close to unity. This writer used such a system with FSK signals at audio frequencies in amateur operation. Precise measurements of results could not be made under these uncontrolled conditions, but they were highly satisfying. It was while using this circuit that W5YM took third place nationally in a RTTY contest in spite of the handicaps of an obsolete receiver and a W2PAT converter.

This circuit certainly deserves considerably more attention from the amateur RTTY fraternity.

26. Attention is now directed to matters of FSK detection in stages following the limiter. Some of the techniques to be discussed are also applicable to systems which do not use limiters. Probably the most common detector in amateur use is a discriminator formed of two tuned circuits, typically tuned to the expected mark and space frequencies. Such a circuit has some deficiencies when used following a limiter. As mentioned earlier, the output of a limiter in the presence of noise has an average frequency equal to the signal frequency, but an instantaneous frequency which swings over a large frequency range. As pointed out by W4EHU, the two-peaked discriminator does not respond to these large frequency excursions, with the result that the discriminator output is not determined by the correct average signal frequency. Instead, it contains "bumps" which occur each time the instantaneous frequency exceeds the limits of discriminator linearity. The net result is signal distortion, usually even harmonic, which is especially harmful to the TTY signal which normally has almost no even harmonic content. The problem may be cured in either of two ways: (a) make the discriminator linear far beyond the expected deviation of the input signal so as to accomodate the excursions in the limiter output, or (b) filter the limiter output before presenting it to the discriminator. The former method was in fact noted in a paper by Sprague in the November, 1944 issue of *Electronics*[50].

27. There are other methods of detecting FSK besides the usual discriminator; and these methods have received very little attention from amateurs. One, of course, is a discriminator based on the 6BN6 gated beam tube. A gated-beam signal converter was described in RTTY, but the gated-beam tubes were not used as discriminators in the usual sense in this design. A rather novel detector is the frequency-meter type, as described in [the ARRL Handbook July 58, QST p. 38]. This detector has interference rejecting properties fundamentally different from those of

the conventional discriminator, and should certainly receive further amateur development and testing.

28. The phase-lock detector has found wide use in telemetering work. In this detector, an oscillator in the receiver (one of the frequency conversion oscillators or the BFO) is arranged for electrical frequency control, by means of a reactance tube or diode modulator. The receiver output is passed through a quite narrow filter to a phase detector which compares the signal phase with that of a local reference oscillator. The phase detector output is used to control the receiver oscillator frequency so that the signal emerging from the receiver is phase locked to the reference signal. The signal controlling the receiver oscillator frequency has a voltage proportional to the incoming signal frequency and thus serves as the output of the detector. An appropriate filter is used between the phase detector output and the receiver oscillator frequency control input. The features of this scheme are the fact that the receiver output is of constant frequency and thus can be passed through a filter which is wide enough only to pass the necessary phase changes; the phase detector can be made highly sensitive; and the network between the detector and the oscillator frequency control can be designed to favor the sort of phase changes to be expected in incoming signals.

29. Another phase lock detector scheme involves fixed-frequency receiver oscillators and a variable frequency reference oscillator phase locked to the receiver output. In this case the receiver bandwidth must be sufficient to accomodate the full frequency excursion of the signal. The output of this detector is obtained either from the reference oscillator control signal or by detecting the reference oscillator frequency excursions with a conventional discriminator. Some degenerate forms of this type of detector are extremely simple; these typically involve an oscillator closely coupled to the input signal so as to be "pulled" in frequency easily. Such detectors have been used in the audio section of television receivers. It is questionable whether they offer any advantage, other than simplicity, over conventional discriminators. but they have yet to be tested in amateur RTTY applications.

30. An interesting frequency-lock detector was used by the Bell System in the Echo I experiments.* This detector also involves a receiver oscillator which can be frequency molulated. The receiver output is passed through a narrow filter and limiter into a narrow discriminator. The discriminator output controls the receiver oscillator in such a way as to tend to keep the receiver output frequency constant.

*Described in several recent issues of B.S.T.J.

In the original application, the Echo I signal was FM of such wide deviation that it could not be demodulated by the usual discriminators. The chief purpose of the frequency lock circuit was to reduce this deviation for convenient detection, while achieving an improvement in S/N at the same time. The interesting feature of this detector is that, like the phase lock detector first discussed, the receiver output bandwidth can be quite narrow compared to the bandwidth occupied by the input signal; and this feature might turn out to be useful with wide-shift FSK which occupies a wide bandwidth rather poorly. Also like the first type of phase detector, it is inherently self-compensating for drift in the frequency of the input signal.

31. It was noted earlier that unless peak signal exceeds peak noise, a limiter can only make matters worse. Most of the foregoing discussion has been concerned with means which can be used to make peak signal exceed peak noise when this condition does not otherwise exist at the receiver input. To summarize, the available techniques are:

(a) limiter input filtering which "fits" the signal as closely as possible, so that interference sufficiently far removed from the signal frequency is attenuated.

(b) methods which improve the operation of limiters and discriminators when peak signal bareyl exceeds peak noise after filtering.

The discussions has been concerned primarily with noise in the form of single-frequency interference. Reference to random noise has not been made because of the rather hairy mathematics involved and because such noise is not be found in a pure state on the amateur bands anway.

31a. A special case not previously discussed is that of fading. Flat fading is a simple variation is S/N which may cause peak noise to exceed peak signal at times. This problem will be discussed in the second instalment of this article. Selective fading is quite different in its action, in that it affects only a narrow band of frequences at a given time. Thus at some times, the system may operate with the marking signal above the threshold and the spacing signal below, or vice versa. Now if the filters and discriminator are well balanced along the frequency scale, the discriminator output will center around zero during fading intervals; and if good post-detection filtering is in use, the net effect will be a temporary large increase in bias distortion. This can be compensated in part by various drift-centering clamper circuits such as used in the W2PAT converter (neon lamps), the Sprague version[50], or the AN/URA-8 circuit. A more refined approach has been patented recently (2,999,925) by Page Communications Engineers, Inc., with the special problem of selective fading in mind.

31b. The subject of post-detection filtering is somewhat controversial. If sufficiently narrow-band limiters are used, it might be that filter sluggishness would aleviate the need for post-detection filtering. With present day filters, it seems that post-detection low pass filtering can be definitely beneficial. The "typical" system (Mark III converter) uses R-C filtering. Very little seems to have been done with L-C filters following the discrimination. A significant problem here is the way in which filter phase shift can louse up signals. Filter ringing is also a problem. RTTY'ers eagerly await the results of your experiments.

31c. The above has been concerned entirely with the case in which peak signal can be made to exceed peak noise by filtering. The second part of this article will deal with the region to the left of the threshold of Fig. 1, in which all filtering attempts are unsuccessful.

32. Now it is time to see what can be done when no amount of prelimiter filtering can make peak signal exceed peak noise. This situation exists with strong interference very close to the RTTY signal frequency, and with weak and fading signals. In this regieme, the limiter must go. A possible exception is Baghdady's oscillating limiter, which might be able to hold on to a signal through certain types of noise even though they be deadly to more conventional limiters. Only on-the-air experience can show this.

33. A first attempt might be the use of a discriminator not preceded by a limiter. The effect of this would be to remove the sharp threshold effect; but it is questionable whether a useful improvement in below-the-threshold improvement would occur except on well-filtered signals. In the general area of weak-signal techniques, a term we shall use for all cases of peak noise exceeding peak signal, we find some which are more appropriate for strong single-frenquency interference and some which are better suited to fading and almost-random noise. In the former case we may assume that the signal exceeds background noise level if only it can be separated from the interference; while in the latter case we have to find means which can identify the signal as being somehow different from the noise and separable from it on that account.

34. In the strong interference case we have interference falling very near the marking and/or spacing frequencies if wide-shift or two-frequency AM signal generation is being used; and falling right in the middle of the signal spectrum if narrow shift is in use. Otherwise filtering would suffice to suppress the interference sufficiently ot permit a limiter to be used for further S/N improvement. With wide shift, if only one of the two "carrier" frequencies is involved, a rather obvious course is to discard one frequency entirely and detect the other as an on-off keyed AM signal. Many signal converters have been built incorporating this possibility of reception. These converters belong to the general class of two-filter units. Normally the selection of FSK or on-off detection is made by a manual switch. A few converters have been built which have only one filter and always operate in the AM detection mode, discarding the other frequency even if it is not perturbed. They therefore do not always make the best of a moderately good signal, but they operate about as well as a more complex unit when interference is encountered.

35. If we are to optimize the single-frequency method of detection of FSK in the presence of interference, we may concentrate on the design of a good single-filter converter, expanding this to a two-filter converter to be used when conditions permit. Hence, we are now concerned with the problem of making the best possible detector for on-off keyed signals. Many techniques applicable to Morse reception are useful here, but we must be careful to take into account the differences between the human ear and the teletypewriter as a receiving instrument. The ear tends to prefer a signal free of filter ringing and spike-type noise and having rise and fall times rather short compared with the signal pulse duration. The machine would like a perfectly rectangular signal envelope but will settle for something much worse.

36. At this point we immediately come to a controversial matter. We might let the machine have whatever waveform we can get out of the detector and let the selector mechanism do whatever it can. Or, we can use some external circuit to generate a rectangular waveform, which will have "chopped" places in it caused by noise, and hope that the short selection interval of the machine will not encounter the chopped places very often. These two possibilities have been the subject of much argument. There is no clear-cut answer from a theoretical standpoint unless the statistics of the noise and the mechanical characteristics of the selector are carefully considered; and in amateur practice the statistics of the noise can get pretty confused. We can only nibble at the edges of the statistical problem by asking just how much we know in advance about what the signal will look like and what the noise is doing to it. We know that no signal pulse will be shorter than 22 milliseconds in duration, and that there is no practical maximum limit to signal pulse duration. We may also know that the signal pulse left the transmitter with a rectangular envelope. In other words, the transmitted signal did not change abruptly in either fre-

DX-RTTY

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Howdy Gang:

Writing a DX Column just a week before the big DX Sweepstakes is rather like a sports reporter trying to describe the Kentucky Derby three days before it takes place. If any of this news seems anti-climatic you will understand that it was written "just before the battle, Mother". We have three new members of the exclusive WAC-RTTY group this month in the person of WØPHM/4, I1RIF and DL6EQ!! Award no. 26 goes to Kent, WØPHM/4 who is now operating as WB-2CVN. He tells me this is the first award he has ever applied for and also he has almost enough confirmations for a second WAC-RTTY as WB2CVN!! Bruno, I1RIF, sent photostat copies of his confirmations and what a beautiful job he did. Bruno's award was the second to come from Europe. Rudi, DL6EQ, sent cards from KR-6MF, ET2US, KH6IJ, LA5LG, PY2BCD and W7ESN to qualify for his WAC on RTTY. His was the third certificate to be sent to Europe. Congratulations to all three for a fine job — your awards will be in the mail very soon.

In spite of the adverse propagation predictions, this Fall seems to be far better than last season for DX work. As I sit here in front of this old typewriter trying to beat the printer's deadline, I1RIF is printing like a local on the printer at my elbow. Even the Stateside QRM doesn't seem to bother his copy. WB2CVN told me just a few minutes ago that he just finished a landline qso with Joe, G3KZI, who was coming across like "gangbusters". If conditions continue like they are at this time it should be a big year for DX on RTTY. Getting back to I1RIF; Bruno has ordered an HT33 linear to go with his "barefoot" HT32 which should really make things interesting this winter. He told K3GIF that he had made a 24 hour propagation test during tape transmissions for that period. One week after the conclusion of this test he had already received reports from South Africa, Japan, Europe, South America and all over North America. Hope to have a complete list of the results of this 24 hour test in a future column. As K3GIF says — "It should make very interesting reading". Bruno is still all "het up" over his trip to Sardinia next summer and is hunting all over Europe for a portable printer to take with him. A new one from Germany is Pete, DL4CW. No other details on DL4CW except he is obviously a GI because he uses lots of "Z" signals. Hi Bill, G3CQE, made a quick trip to Germany to check up on a large allotment of TTY gear that was available in Frankfurt. He "shook up" the Editor-in-Chief by phoning Arcadia by long distance to inquire about the current price on American built printers. Bill is once again quite active and many of the Stateside gang have reported working him in the past two weeks. Bob, G3GNR, has returned from his honeymoon and is now trying to figure out how to talk his new bride into learning the code and getting on RTTY. Welcome to the club, Bob!

The South African contigent is back in the news again with all the old standbys coming on strong. Several new ones have been logged in the past month to supplement the efforts of ZS1FD, ZS6UR and ZS1DE. Dave, W9DPY, had a fine four-way contact that included ZS6UR, G3CQE and KP4GN. He reports that all signals were in the S-9 region which is good news for the coming DX season. I might point out that all the news reported so far has been around 14.090. Nothing has been received so far to indicate any DX activity on either Forty or Fifteen. PY2BCD is still active on 14,090 and quite a few have reported contacts with him. Word has been received that Jack Pitts has arrived in Venezuela and is teaming up with Frank to activate YV-1EM. These two stalwarts should really cut quite a swath during the next few months. Both are excellent operations and YV1EM always puts a big signal into the States. Many of the gang will recall the king-size pileups that YV1EM created during the SS last year!! Erosa, XE1BI, reports that he and XE1YJ are going to join forces for the Contest this year. This certainly should make another combination that should be hard to beat.

One hour after returning from a Month's vacation your DX Editor came up with a new RTTY Country in the person of KH-6COY/KW6 on Wake Island. His handle is Arnold and what a beautiful signal he puts into the West Coast using a Johnson Valiant and a 75S-1. Arnold says he will be sitting on 14,090 every Sunday at 0300Z looking for contacts. His mailing QTH is: Officer in Charge, U.S. Army Radio Station — Wake, APO 101, Wake Island, U.S. Forces. To avoid pile-ups Arnold will listen for answers to his calls five to ten KC off of his transmitting frequency. Keep this in mind when trying to raise KH6COY/KW6.

The "big three" of VK3KF, ZL3HJ and ZL1WB have now been joined by VK2EG who has finally received the brush motor for his Model 26. All these lads are very consistent every week-end from about 0400 until the band goes out. Eric, VK3KF, survived a terrific storm this past month — the only casualty being part of his kitchen roof and the tree that supported his Forty meter wire. He is presently back in business with his usual fine signal and consistent operation.

Our old Buddy Cas, Ex-KR6AK, writes that instead of drawing duty in Viet-Nam he is on his way to Korea. He is hoping to get on RTTY with an HL call and will keep us informed as soon as he arrives there and looks the situation over. He is currently looking for some info on a good Transistor TU circuit because of the fact that he is quite restricted to weight. We could sure use another Asian Contact on FSK, Cas! — and speaking of Asia on RTTY — KR6LJ tells me that Cole, KR6MF, is now in Japan and should be showing up with a KA2 call soon. When he manages to get his gear hooked you can bet that Cole will be on TTY! Prospects for Asian QSO's are looking metter.

Well, Gang, this is it for now — have to give the gear a strong going over for the big shin-dig next week. Cu next month.

73
Bud W6CG

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(Con't from page 13)

quency or amplitude in an interval of time at least 22 milliseconds long which started at some unknown time. This is about all we know in start-stop operation; if we were operating synchronously we would also know after a time just about when to expect signal pulses to begin and end (which would be quite helpful). From this scant knowledge, plus an observation of what comes out of the receiver, we must attempt to reconstruct the details of a process which took place at the distant transmitter.

— TO BE CONTINUED —