DEVELOPMENT -12KC BANDWIDTH MODIFICATION FOR WRC-1

GENERAL DYNAMICS | ELECTRONICS

Submitted to:

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1.0 INTRODUCTION

It is the understanding of General Dynamics/Electronics that there is a need in Naval communications for receivers and transmitters with channel bandwidths of 6 kc for single sideband signals and 12 kc for double sideband AM signals.

The AN/WRC-1 Radio Set currently being produced at General Dynamics/ Electronics under Contracts NObsr-87614 and NObsr-89368 (FBM) has a designed channel bandwidth of 3.5 kc in single sideband and 7 kc in AM. However, the basic design of the AN/WRC-1 Radio Set is such that it is adaptable to modifications to provide the desired increase in channel bandwidths.

All of the work performed for BuShips to date on the AN/WRC-1 has been conducted by General Dynamics/Electronics, including the original development and design under Contract NObsr-77628, the redesign for production and pilot production under Contract NObsr-87614 and the full production under Contract NObsr-89368 (FBM). General Dynamics/Electronics would like to place the experience and competence gained in the performance of these contracts at the disposal of the Bureau of Ships.

To this end we respectfully submit this unsolicited proposal for modification of the present AN/WRC-1 Radio Sets for 6 kc single sideband and 12 kc double sideband channel bandwidth.

1.1 Discussion of Problem

The purpose of this proposal is to present a technical discussion on how General Dynamics/Electronics would modify the R-1051/URR high frequency receiver and the T-827/URT transmitter to provide the Navy with a high frequency receiver in accordance with Paragraphs 3.2.2.2.6.4 and 3.2.2.2.6.3 of the DCS Engineering-Installation Standards Manual (DCA CIR 175-2A). The R-1051/URR with its 3 kc bandwidth in USB, LSB, and its 6 kc bandwidth in AM would be modified to a 6 kc bandwidth in USB, LSB, and 12 kc in AM. The LSB, USB, and compatible AM bandwidth of the T-827/URT transmitter would be modified to 6 kc. With the receiver and the transmitter in the Independent Sideband mode, the use of external demultiplexing will provide the four desired 3 kc channels.

The main objectives of this proposal are:

1. To examine the circuitry along the signal path of the R-1051/URR and the T-827/URT to determine where redesign is a definite requirement.

2. To endeavor to follow a design plan which will result in a minimum amount of electrical and mechanical modification to the existing R-1051/URR receiver and the T-827/URT transmitter.

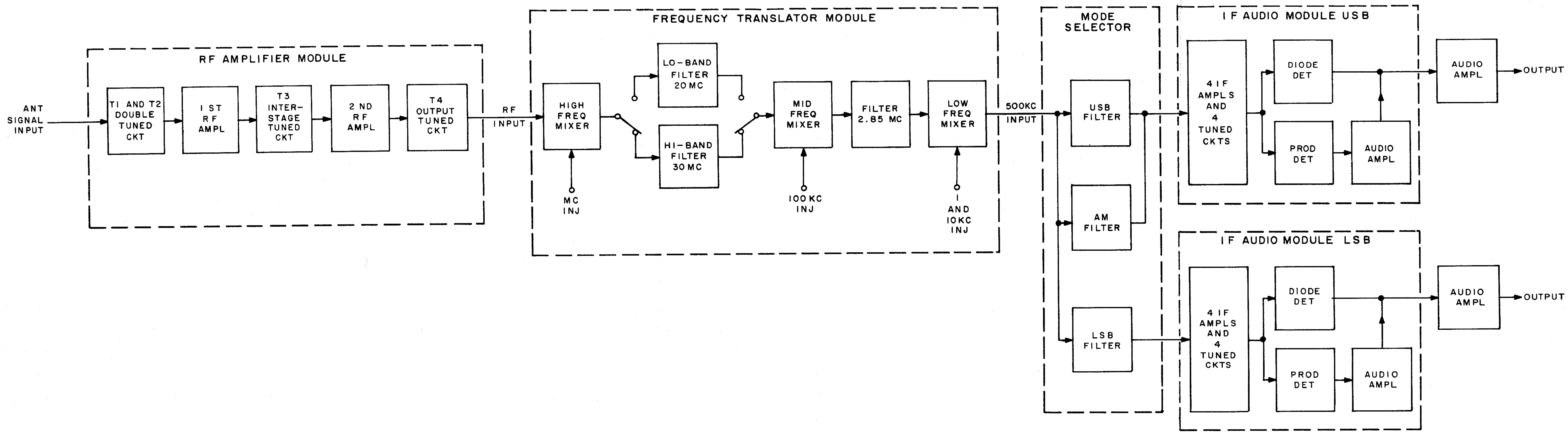

Figure 1. Signal Path Only In The R1051/URR Receiver.

2.0 TECHNICAL DISCUSSION

2.1 R-1051/URR RECEIVER

Figure 1 is a simplified block diagram of the signal path omitting the Frequency Synthesizer Module and Frequency Standard Module, because they would require no redesign if the existing IF frequencies are retained.

An investigation of the RF Amplifier bandwidth is necessary to ensure that negligible bandwidth limiting of the new wider 12 kc AM occurs in the RF amplifier. As shown in Figure 1, the RF amplifier has four tuned circuits, a double tuned input (T1 and T2), a single tuned interstage (T3), and single tuned output (T4). Each tuned circuit coil is changed for every integral megacycle band resulting in a turret of 112 coils covering the 2 through the 29 mc bands. In Figure 2, the calculated selectivity attenuation of the individual tuned circuits is shown normalized for percent frequency deviation from center frequency. Therefore, Δf is one-half the total bandwidth at the attenuation in decibels under consideration. The composite selectivity curve for RF amplifier results from the addition of the db attenuation of the individual tuned circuits at each percent frequency deviation. The tuned circuit Q's shown in Figure 2 are representative of the actual circuit Q's within ±15 percent.

Under the new bandwidth conditions of 12 kc, it appears that a RF amplifier bandwidth of 20 kc for 1 db down on the overall selectivity will be a good compromise for tracking, temperature, and Q' variation. From Figure 2 it can be observed that a .25 percent frequency deviation from center frequency are the conditions for the composite selectivity curve to meet the 1 db limit. Since a 10 kc deviation (one-half the total 20 kc) is desired, the upper center frequency minimum of 4 mc satisfies the .25 percent condition. Therefore, modification of the bandwidth of only the 2 mc, 3 mc, and possibly the 4 mc bands will be required. The remaining 5 mc through 29 mc band should be more than adequate as they now exist.

Now let us examine the modification required on the first three bands. Examining Figure 2 again, at the .25 percent deviation the curves of the composite selectivity and the single tuned Q = 100 (this tuned circuit is the T3 interstage) are

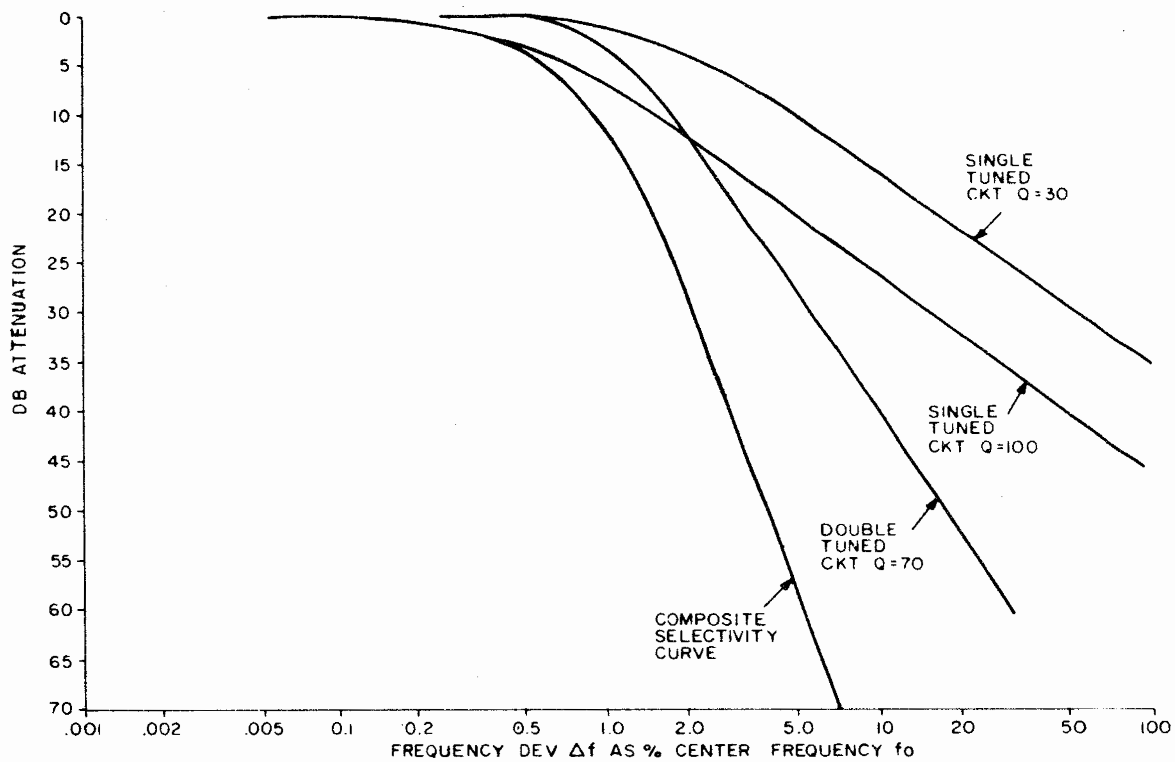

Figure 2. Computed Normalized Selectivity Curves for RF Amplifier Module.

essentially coincident. The double tuned input and the single tuned output (Q = 30) do not yet make any appreciable contribution to the attenuation. Therefore, the bandwidth for the 2, 3, and 4 mc bands should be increased by lowering the coil Q of T3 until the desired bandwidth is achieved. Since the 2 mc band will require the largest Q reduction, it is necessary to see that the new value is within a satisfactory range so as not to adversely affect the amplifier operation. The new Q can be calculated from Figure 2 and the result for the 2 mc band is 50. This reduction in interstage Q from 100 to 50 will not affect the amplifier gain or crossmodulation characteristics at this low frequency to be of any consequence. The new lower coil Qs can be obtained by simply reducing the wire size used in manufacturing the coils.

In the event that the bandwidth reduction in the first three megacycle bands appears tolerable in operation, the RF amplifier module could remain unchanged from the one presently used in the R1051/URR receiver.

2.1.1 TRANSLATOR MODULE

In the Translator Module, the output from the RF amplifier is mixed with stable injection frequencies generated in the frequency synthesizer to produce three IF frequencies. The first IF is either 20 ± .5 mc or 30 ± .5 mc depending on the megacycle frequency selection made at the receiver front panel. The output of the 1st mixer is gated to the correct filter both of which have an overall one megacycle bandwidth. Figures 3 and 4 are some typical response curves made from presently used filters in the R1051/URR receiver. The extention of the signal bandwidth from 3 kc to 6 kc is obviously negligible to the wide bandwidth utilized in these filters.

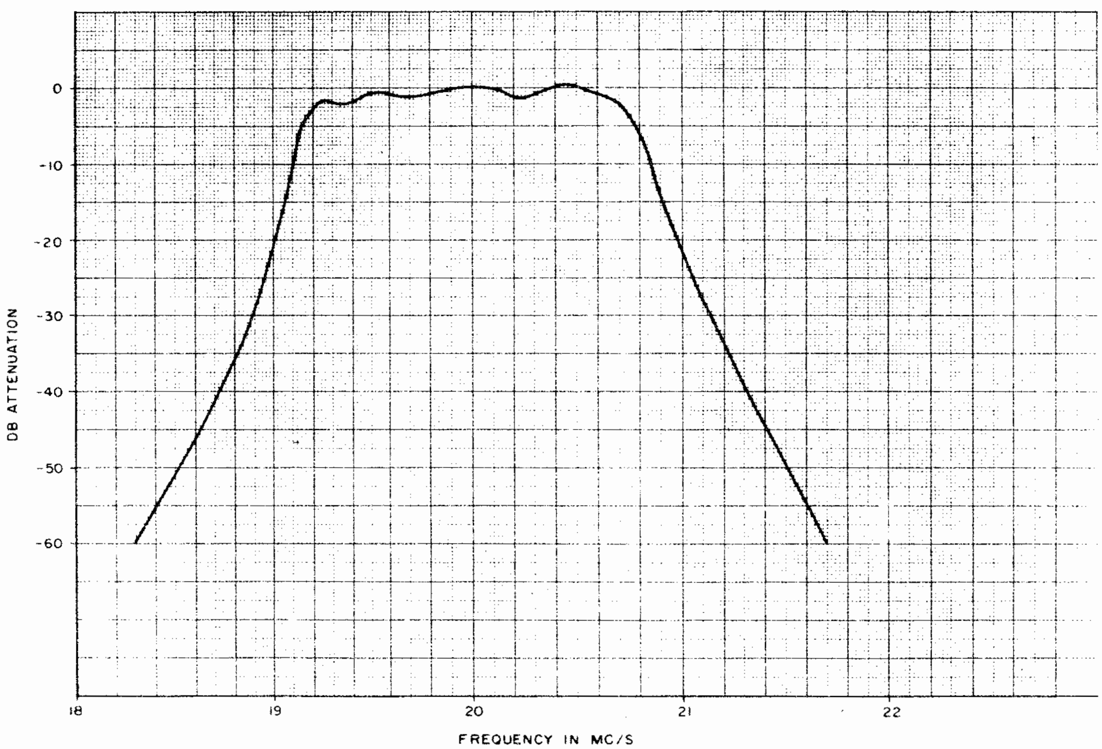

Figure 3. Typical 30 mc Filter In The Translator Module.

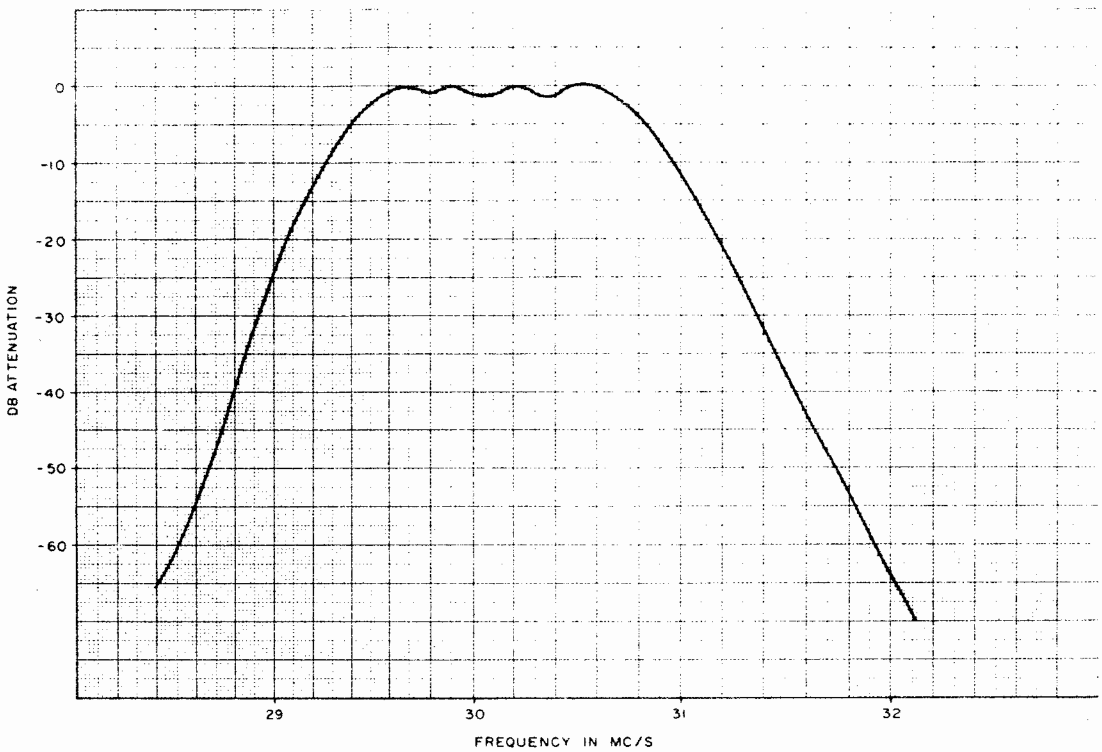

Figure 4. Typical 30 mc Filter In Translator Module.

Conversion in the 2nd mixer generates a 2nd IF frequency which ranges from 2.8 to 2.9 mc while transversing across each received megacycle band. A 2.85 mc filter with a greater than 100 kc bandwidth provides the selective load for the 2nd mixer output. As can be observed from the frequency vs. attenuation of a typical filter in Figure 5, the bandwidth available is sufficiently wide to encompass the new desired bandwidth requirements.

The output of the 3rd mixer is at 500 kc. This 3rd IF frequency is then routed to the Mode Selector module. Therefore, the translator module should be usable in exactly the same form it presently takes in the existing R1051/URR.

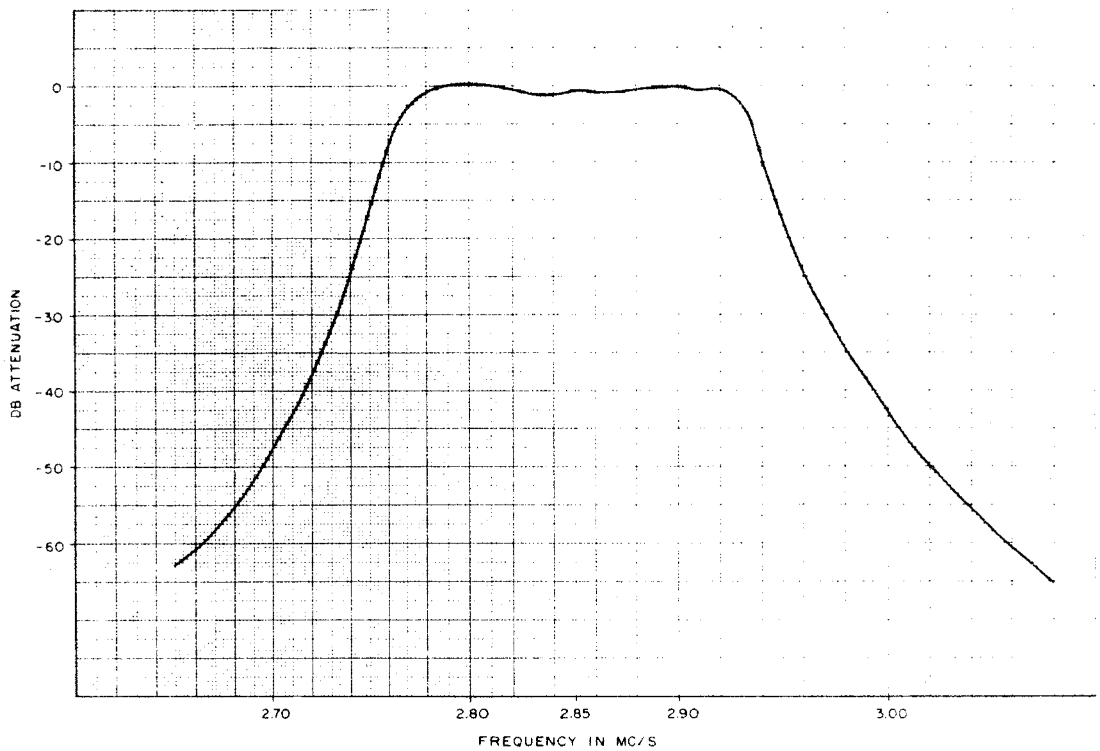

Figure 5. Typical 2.85 mc Filter In Translator Module.

2.1.2 MODE SELECTOR MODULE

The Mode Selector Module contains the three highly selective 500 kc mechanical filters; USB, LSB, and AM. These mechanical filters primarily establish the signal channel bandwidth and near-channel selectivity characteristic of the R1051/URR. Here is the first place in the signal path that a major change must be made. The simplest and most direct change would be filters with the new wider bandwidths in the same mechanical package. Figure 6 shows a view of how the mechanical filters are mounted in the casting of the Mode Selector Module. The L-shaped board to the right of the filters is a printed circuit board.

Since no off-the-shelf filters in this configuration with the increased bandwidth characteristics existed, the supplier of the presently used filters was requested to submit what would be a reasonable filter specification for this configuration. Table I illustrates the characteristics of the proposed USB filter and compares it with the USB filter in present use. The LSB filter would be a mirror image to the USB filter. Table II illustrates the characteristics of the proposed AM filter and compares it with the AM filter in present use.

TABLE I

Single Sideband Filter Characteristics at 25^{o}C		
	Present Filter	Proposed Filter
Carrier Frequency Pass Band	500 kc 300 to 3500 cps (At 3 db down points)	500 kc 450 to 6,000 cps (At 1.5 db down points)
Maximum Pass Band Ripple	3 db	1.5 db
Carrier Frequency Attenuation	10 db minimum	10 db minimum
60 db Attenuation Frequencies	800 cps Below carrier and 5300 cps above carrier	2000 cps Below carrier and 9000 cps above carrier
Insertion Loss	16 ± 2 db	8 db maximum
Spurious Response	45 db	50 db

TABLE II

AM Filter Characteristics at 25°C		
	Present Filter	Proposed Filter
Carrier Frequency	500 kc	500 kc
Pass Band (Total Double Side Band)	7 kc (At 3 db down points)	12 kc (At 2 db down points)
Maximum Band Pass Ripple	3 db	2 db
60 db Down Band Width	19 kc	Approx. 24 kc
Insertion Loss	16 ± 2 db	8 db maximum
Spurious Response	45 db	50 db down 450 kc to 550 kc

The skirt selectivity and minimum carrier frequency rejection of the proposed filter remain reasonably relaxed from the filter characteristics depicted in Figure 3.2.2.2.6.3.3 of the DCS Engineering-Installation Standards Manual. From an investigation in the possibility of the use of a crystal filter to replace the mechanical filter for better skirt selectivity, a source responded with the following filter size 1.5 by 1.75 by .88 inches. This filter size is shown in Figure 7 in a one-to-one scale as is the Mode Selector Module in Figure 6. Four other suppliers refused to quote on the crystal filter in that size or smaller with the specifications asked for. From Figures 6 and 7, the extent of a redesign to crystal filters is readily surmised. Generally, the requirements for AM are not as stringent as for SSB. If a slight shift in passband with long term aging can be tolerated, the latest developments in ceramic ladder filters offer interesting possibilities from the standpoint of reduced cost, lower passband ripple, sharper skirt selectivity, lower insertion loss, and improved spurious response

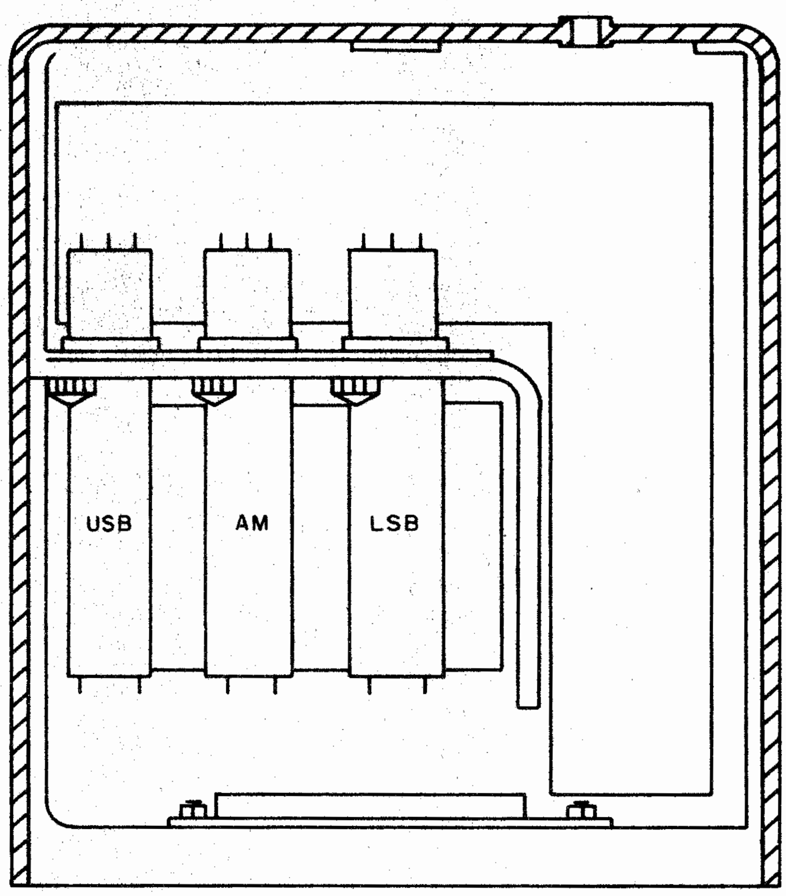

Figure 6. Mode Selector Module.

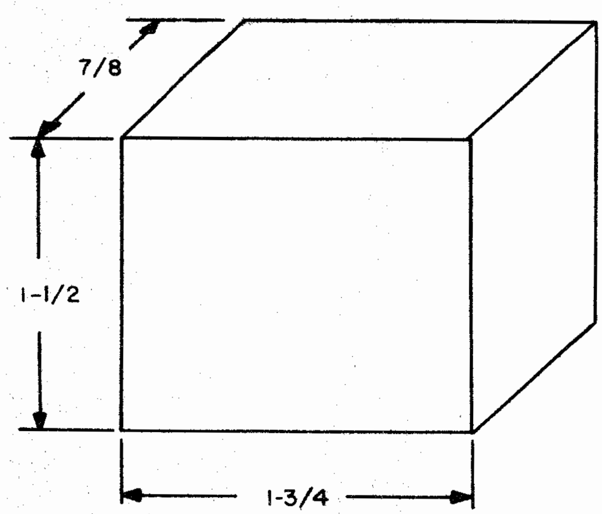

Figure 7. 500 kc Crystal Filter Package Size (3 required).

characteristics than mechanical filters. Ceramic filter material is presently available whose resonant and anti-resonant frequencies vary with time at a rate of only 0.06 percent per ten years. Physical packaging of these ceramic filters can be designed to permit installation in place of the presently used mechanical filters, thus eliminating costly mechanical redesign of the Mode Selector Module.

By using filters with the same physical dimensions as are in present use, slight circuit modifications to accommodate the new filters should make modification of the Mode Selector Module relatively straightforward.

2.1.3 IF/AUDIO MODULE

The IF portion of the module consists of four amplifier stages with tuned circuit interstage coupling. The overall bandwidth of the four tuned circuits poses a possible bandwidth limiting problem. The tuned circuit Q's are presently approximately ten in each case. The overall 3 db bandwidth for the four stages is 21 kc (50 kc per stage times .43 reduction factor for four stages). At 6 kc deviation from the 500 kc center frequency, there would be about a 1 db attenuation from the four IF stages. If it should eventually appear advisable to even reduce this 1 db somewhat, the simple expedient of changing the swamping resistor values across the tuned circuits should handle this situation adequately. Sufficient gain is available in the four stages so that no problem should be offered from this source.

The second major bandwidth limiting (the first was the mechanical filters) would take place in the output circuit of the product detector and in the audio amplifier circuitry. The present audio bandwidth of 3500 cps would have to be extended to at least 6500 cps. This redesign would involve some changes in the audio transformers to ensure response and distortion capabilities. Circuit component changes would be necessary but undoubtedly the same circuit configuration could be maintained. The audio response is necessary not only from amplitude considerations but also from phase considerations. Meeting the proper phase conditions are necessary to ensure that the envelope delay specifications of 500 microseconds for the receiver is also met.

To summarize, redesign and modification of the R1051/URR high frequency receiver to extend its SSB bandwidth to 6 kc and its AM bandwidth to 12 kc will require changes in at least two of the receiver's modules; Mode Selector Module and IF/Audio module (two IF/Audio modules are used per receiver). In the mode selector, the approach will be to use mechanical filters developed to the new bandwidths. The use of a ceramic filter in the AM position remains a possibility.

2.2 T-827/URT TRANSMITTER

The modules in the signal path of the T-827/URT Transmitter are shown in the block diagram, Figure 8. The Translator and the RF Amplifier modules are identical to those used in the R1051/URR Receiver and the comments appearing under the Receiver discussion apply. Of the remaining modules in the T-827 Transmitter, the present Transmitter Audio module bandwidth is more than adequate for the proposed 6 kc sideband channel since its frequency response is flat to beyond 6 kc, falling to 0.5 db down at 10 kc.

As in the case of the Receiver, the mechanical filters in the Mode Selector module primarily determine the passband and near-channel selectivity characteristic of the T-827/URT Transmitter. The present 3.5 kc bandwidth filters must be replaced by 6 kc filters identical to those proposed for the Receiver Mode Selector.

The bandwidth of the present Transmitter IF module may be marginal in that the response to 6 kc each side of the center (or carrier) frequency is down almost 1 db. Should this high frequency channel end roll-off added to the possible additional 1.5 db decrease due to the sideband filters be unacceptable, the band edge response fall-off can be compensated by changing one of the two tuned circuits in the IF to an overcoupled double tuned circuit. Ample space exists in the Transmitter IF module to accomplish this.

For various reasons, such as economy of space, ease of tone shift keying, etc., the present FSK Tone Generator utilizes multivibrator circuitry with resulting square wave rather than sinewave tone output. By designing the multivibrator circuits for square wave outputs for precisely equal on-off duty cycle, no even harmonics of the fundamental output frequency are generated, but only the odd harmonics. Thus even for the lowest FSK tone required - the 1575 cps "space" tone for 2000 cps center frequency operation (2000-425=1575 cps) - the first odd harmonic encountered is the third at 4725 cps. This is well beyond the pass band of the present 3.5 kc sideband filter and thus only the desired single sinusoidal tone is transmitted in FSK. Unfortunately with the proposed change to the 6 kc bandwidth filter, the third harmonics fall either in the pass band or are not far enough into the reject band to be attenuated sufficiently. Rather than redesigning the FSK Tone Generator completely and thus requiring replacement of the present module with a new unit, a simpler solution is to add a low pass filter between output of present FSK module and the input of the upper sideband Transmitter audio module. A three section filter consisting of a constant K-section and two M-derived sections with M's chosen to place the maximum attenuation notches at 4725 cps and 6375 cps (the third harmonics of the "space" tones for the 2000 cps and 2550 cps center frequency operation respectively) should suffice since the combined attenuation of the low-pass filter and the 6 kc sideband filter should adequately attenuate the third harmonics of the "mark" tones for both the 2000 cps and 2550 cps center frequencies (7275 cps and 8925 cps respectively). Room for mounting a low pass filter is available on the rear-of-panel protective bracket presently used on the Transmitter.

To summarize, the changes required to increase the channel band width of the T-827/URT Transmitter from 3.5 kc to 6 kc are:

1. Replace the two sideband filters in the Transmitter IF module.
2. Add a low pass filter to suppress FSK tone third harmonic outputs.
3. Possibly replace the printed circuit board in the Transmitter IF module with one incorporating a double-tuned circuit.

All of the above changes should be capable of being made by means of field modification kits.

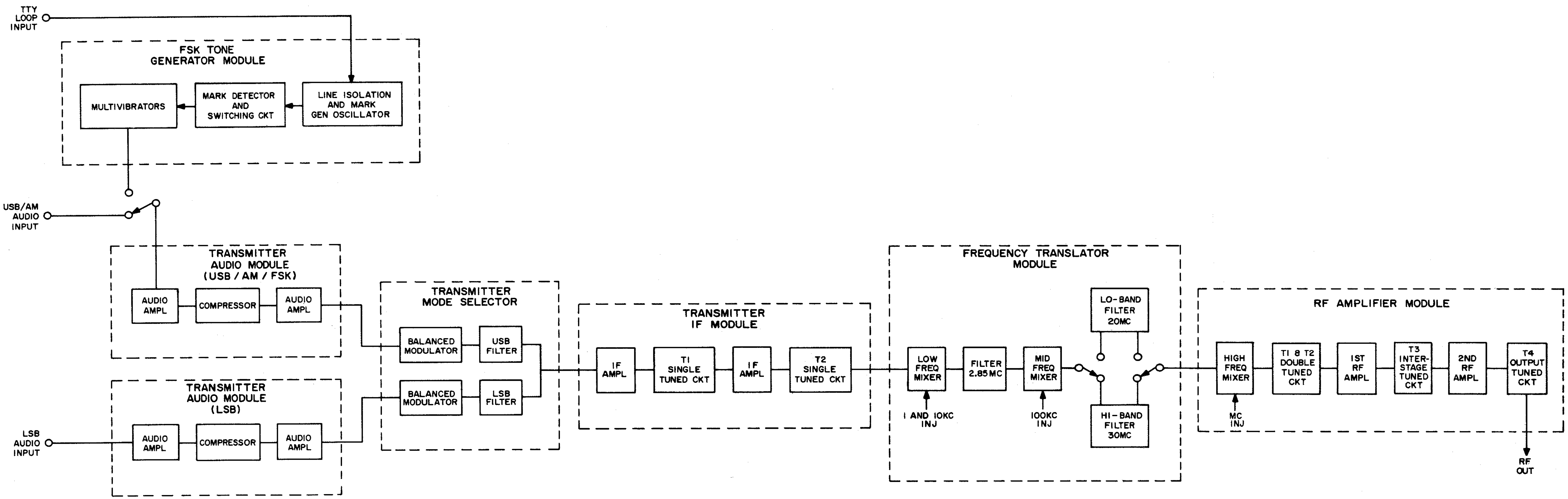

Figure 8. Signal Path Only in the T-827/URT Transmitter.