# A WIDE-BAND MULTICHANNEL TRANSMISSION SYSTEM FOR USE WITH 5 MHz COAXIAL LAND LINES

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**Summary** An increasing number of telemetry systems have considerable distance between receiving sites and main ground stations, resulting in a need for multichannel wide-band communications systems. An operational system is described which permits the wide-band DC to 120 kHz video or predetection IF 450 kHz ±150 kHz signals from six receivers to be transmitted over one land line to the remote ground station.

**Introduction** There is a growing need to telemeter multichannel wideband analog and digital data across 5 MHz land lines. The data may come from many sources but the prime concern of this paper is the signals from receivers either in the form of a DC to 120 kHz video or a predetection FM carrier down-converted to a 450 kHz IF. If the receiver signals are to be transmitted over lines in the form of a frequency shared multiplex, experience has shown that operational adjustments must be kept to an absolute minimum.

The land line multiplex system must function over a wide range of input levels and formats; in addition, the performance of any one channel must not depend on the presence or absence of any other channel. That is, each channel of the multiplex must be considered a separate, independent land line link.

A multiplex of FM channels meets these demands since the input of each channel can be either a 450 kHz VCO or a 450 kHz FM predetected signal. In either case, it can be hard limited and filtered in order to maintain a constant channel level independent of the level from the receiver. By keeping the VCO's and discriminators at 450 kHz, the same frequency as the receiver IF's, the video or predetection signals can be processed in an identical manner. For instance, the channel output at the far end of the line is identical for both video or predetection signals, namely a 450 kHz ±150 kHz FM carrier at a level of 6 volts peak-to-peak into a terminated 75 ohm cable. At this point. the signal can be demodulated by a 450 kHz discriminator or recorded as a 450 kHz predetection signal and later played back through the demodulator.

Wide-band multiplex data transmission systems make it possible to use television grade cables and microwave links for efficient transmission of multichannel wide-band (DC to 120 kHz) analog signals or 400 kilobit digital data. Multiplexing equipment with six channels on a single 5 MHz bandwidth link has been implemented with distortion levels below 2.5% and worst case crosstalk levels at least 40 db below full scale output.

A prominent feature of the system is its compatibility with the commonly used 450 kHz predetection down conversion center frequency; that is, data may enter the system either as a baseband signal which is converted to a 450 kHz FM carrier, or a 450 kHz predetection carrier may be fed directly into the system, bypassing the FM modulator.

A second system of eight channels on the 5 MHz line can also be implemented. That system is intended primarily for digital data transmission with eight parallel bits, each aligned in time, transmitted at a rate of 250 K words per second.

The operation of the six-channel multiplexing system may best be described using the block diagram of Figure I which shows the modulation translation, and filtering used to format the data for transmission. Each baseband signal is applied the modulation input of an FM oscillator with center frequency of 450 kHz and full scale deviation of ±150 kHz. Oscillator outputs are then filtered to remove harmonics and protect adjacent channels against over modulation and the carriers are heterodyned to their assigned center frequencies. After additional filtering to attenuate undesired spectral components in the converter outputs, the carriers are summed to form a multiplex for transmission. The line driving amplifier output is single ended at an impedance level of 75 ohms with composite level adjustable from 0 to 3 volts peak-to-peak into a terminated 75 ohm line.

At the receiving terminal, each carrier is separated from the multiplex by means of a bandpass filter and heterodyned to 450 kHz for additional filtering and demodulation. Output frequency response is limited to 120 kHz for analog signals requiring low crosstalk and distortion but for high bit rate digital signals, the system passband can be increased to allow 400 kilobit/second signaling. Output impedance is 75 ohms with a full scale level of 6 volts peak-to-peak into a terminated line.

The technical difficulties of such systems arise in the areas of filtering and up-down converting. The filtering is difficult because four steep-skirted filters are cascaded in each channel yet maximum frequency response and phase linearity are required.

Referring to Figure 2, one sees the multiplex’s channel spacing and guard band structure. In addition, it gives a view of the filter problem. In each channel there is a 450 kHz filter which passes the limited 450 kHz input. This filter has the same characteristics as the Channel #1 filter shown in Figure 2. From the 450 kHz filter, the signal goes through the up translator and then through an output filter such as the #2 channel filter also shown in

Figure 2. This double filtering is again repeated in the down translator. Normal linear phase filters such as a Gaussian filter would not suffice because of inadequate selectivity and progressive bandwidth shrinkage. This system's filters are phase equalized lattices in which the phase equalization and the amplitude attenuation requirements have been integrated into a single design. The envelope delay variation must be held to very tight tolerances in order to achieve a worst case dynamic distortion less than 1. 5% for any single filter and less than 2.5% for four filters cascaded.

The second difficult area is in the up and down frequency translation which must be accomplished without generating in-band intermodulation products. This difficulty has been minimized by using a switching type modulator with fast diodes switched by a high rise time square wave of current. This technique reduces the switching transient time to a value that permits the baseband to be translated up beyond 6 MHz with intermodulation products less than 0.5% of the desired signal.

Both the filtering and the frequency translation is performed in a unit that is a two and one-half inch wide module with a plug-in tuning unit. The module contains the modulator plus limiters and amplifiers while the tuning unit contains the crystal local oscillator and two filters such as shown in Figure 2. The same translator module is used in both the transmit or the receiver terminal system interchangeably.

**Electrical Characteristics of the Baseband Mode (Data into the VCO's).**

A. Input signal: Single ended input with ±2. 5 volt span considered standard with differential input and lower level input spans also available.
B. Input impedance: Greater than 100 K ohm shunted by less than 150 pf or line matching levels.
C. Carrier Frequencies and Deviations: 450 kHz, 1326 kHz, 2202 kHz, 3078 kHz, 3959 kHz, 4830 kHz, all full scale deviations ±150 kHz.
D. Multiplex level: Adjustable from near zero to at least 4 volts peak-to-peak open circuit.
E. Multiplex impedance: 75 ohms nominal, single ended.
F. Receiving system input impedance: 75 ohms nominal.
G. Receiving system dynamic range: Satisfactory operation on clean signals from less than 0.5 volts peak-to-peak to more than 3.0 volts peak-to-peak.
H. Baseband 3 db frequency response: DC - 120 kHz within ±2 db for analog applications and bit rates to 250 KBPS.
I. Distortion: Total harmonic distortion less than 2.5% for any baseband frequency.
J. Crosstalk and noise: For channels operating normally, rms crosstalk and noise is at least 40 db below peak-to-peak output. Under conditions of overmodulation, rms crosstalk and noise is at least 26 db below peak-to-peak output.
K. Transient response: Transient overshoot is less than 5%.

L. Interchannel delay uniformity: Channels 2 through 6 have a nominal delay of 20 $\mu$sec. and are uniform within ±0.5 $\mu$sec. Channel 1 has a nominal delay of 10 $\mu$sec. but can be equalized to match channels 2 through 6.
M. Output level: Adjustable to 6 volts peak-to-peak into a terminated line.
N. Output impedance: 75 ohms single ended. Short or open circuit loads will not cause instability or damage.

**Electrical Characteristics of the Six-Channel System in Predetection Mode**

A. Input signal: 450 kHz ±150 kHz carrier, level ranging from 0.5 volt peak-to-peak to 10 volts peak-to-peak for normal operation, single ended.
B. Input impedance: 75 ohms nominal.
C. Carrier Frequencies and Deviations: 450 kHz, 1326 kHz, 2202 kHz, 3078 kHz, 3959 kHz. 4830 kHz, all full scale deviations ±150 kHz.
D. Multiplex level: Adjustable from near zero to at least 4 volts peak-to-peak open circuit.
E. Multiplex impedance: 75 ohms nominal, single ended.
F. Receiving system input impedance: 75 ohms nominal.
G. Receiving system dynamic range: Satisfactory operation on clean signals from less than 0.5 volt peak-to-peak to more than 3.0 volts peak-to-peak.
H. Baseband 3 db frequency response: DC - 120 kHz within ±2 db for analog applications and bit rates to 200 KBPS. Wider band lowpass filters to accommodate 400 KBPS can be provided.
I. Distortion: Total harmonic distortion less than 2.5% for any baseband frequency.
J. Crosstalk and Noise: For channels operating normally, rms crosstalk and noise is at least 40 db below peak-topeak output. Under conditions of overmodulation, rms crosstalk and noise is at least 26 db below peak-to-peak output.
K. Transient response: Transient overshoot is less than 5%.
L. Interchannel delay uniformity: Channels 2 through 6 have a nominal delay of 20$\mu$sec. and are uniform within ±0.5$\mu$sec. Channel 1 has a nominal delay of 10$\mu$sec. but can be equalized.
M. Output level: Adjustable to 6 volts peak-to-peak into a terminated 75 ohm line.
N. Output impedance: 75 ohms single ended. Short or open circuit loads will not cause instability or damage.

**Eight-Channel Digital System**

The 5 MHz bandwidth of the line can be arranged to provide eight channels. The first at 500kHz and each thereafter separated by 600 kHz. This gives a sequence of center frequencies of 500, 1100, 1700, 2300, 2900, 3500, 4100, 4700 kHz. At a bit rate of 250 KBPS, the crosstalk between adjacent channels would be at least 26 db down, which is more than adequate for digital transmission. The digital system block diagram is not as formal as the analog one because the digital information may be put on the line not only as FM but as pulse shift keyed modulation, etc., depending on the requirements of the digital interface equipment in a particular situation.

Physical Characteristics

Figure 3 presents a front panel outline drawing for the end terminal or receiver system. It is seen that the six channels each have a down converter and an FM demodulator, all contained in a front panel space 7" high by 19" wide. Each demodulator has a front panel zero and sensitivity control. The converters require neither front panel nor internal adjustments. Also included in this space are the power supplies and air circulation blowers. The total system weighs less than 75 pounds and requires less than 300 watts of 60 Hz line power. Since the sending end of the system is similar in size, weight and power requirements, it is not shown. The controls on the sending end consist of a zero and deviation sensitivity control on each VCO. no controls on the converter and a level control on the output amplifier. The eight-channel digital system also requires a space 7" high by 19" wide. In addition, since the outputs might require pulse shaping, an additional space would be needed depending on what signal format the digital interface demands.

**Acknowledgment** Mr. Keith M. Wooded must be given credit for the operational specifications and the idea of requiring all demodulators and VCO's to run at the same frequency, namely the predetected IF of 450 kHz. These ideas provide a versatility and ease of maintenance and spares that contribute markedly to the ultimate usefulness of the system.

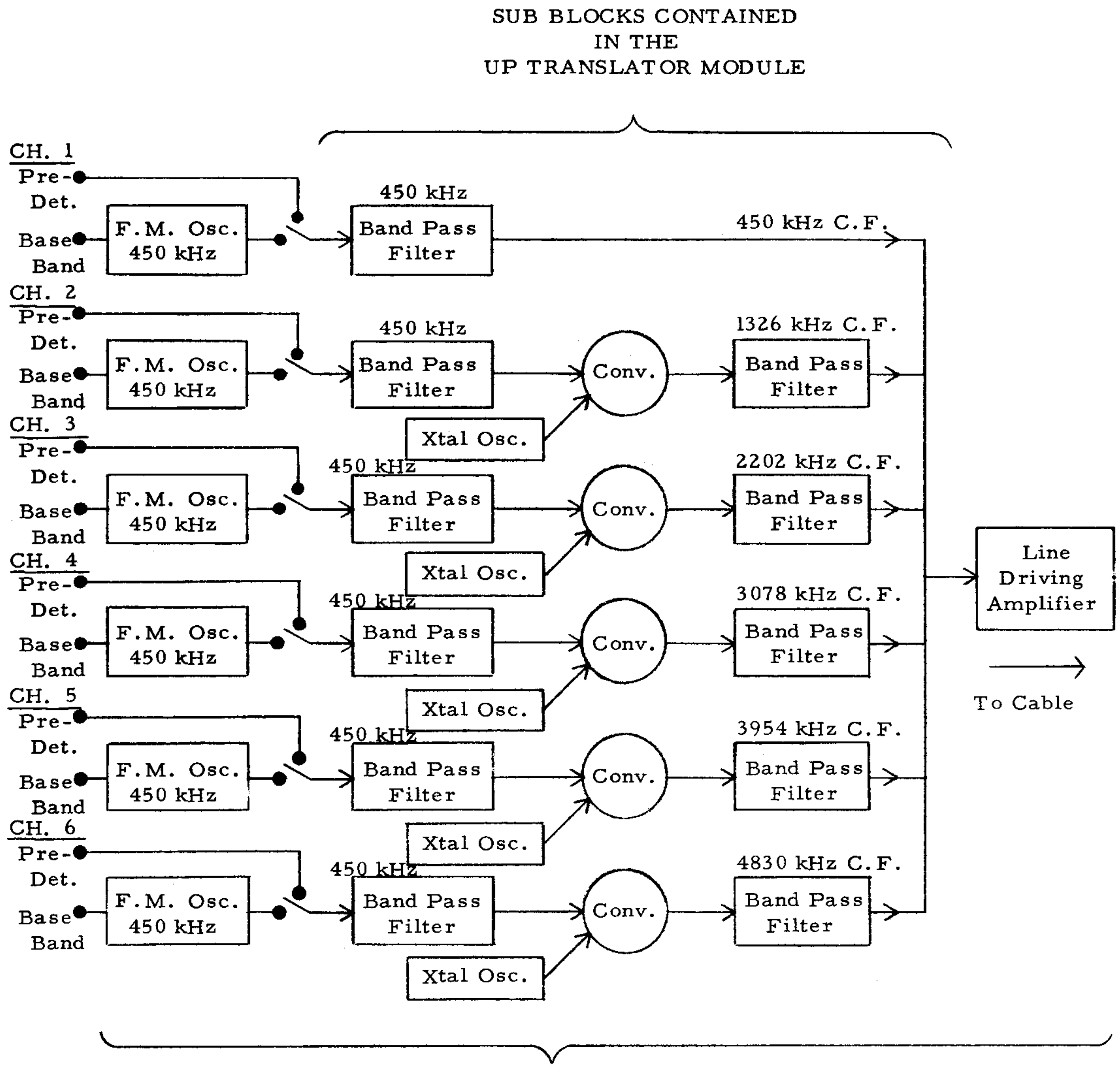

SUB BLOCKS CONTAINED
IN THE
UP TRANSLATOR MODULE
CH. 1
Pre-
Det.
Base
Band
F.M. Osc.
450 kHz
450 kHz
Band Pass
Filter
450 kHz C.F.
CH. 2
Pre-
Det.
Base
Band
F.M. Osc.
450 kHz
450 kHz
Band Pass
Filter
Conv.
Xtal Osc.
1326 kHz C.F.
Band Pass
Filter
CH. 3
Pre-
Det.
Base
Band
F.M. Osc.
450 kHz
450 kHz
Band Pass
Filter
Conv.
Xtal Osc.
2202 kHz C.F.
Band Pass
Filter
CH. 4
Pre-
Det.
Base
Band
F.M. Osc.
450 kHz
450 kHz
Band Pass
Filter
Conv.
Xtal Osc.
3078 kHz C.F.
Band Pass
Filter
CH. 5
Pre-
Det.
Base
Band
F.M. Osc.
450 kHz
450 kHz
Band Pass
Filter
Conv.
Xtal Osc.
3954 kHz C.F.
Band Pass
Filter
CH. 6
Pre-
Det.
Base
Band
F.M. Osc.
450 kHz
450 kHz
Band Pass
Filter
Conv.
Xtal Osc.
4830 kHz C.F.
Band Pass
Filter
Line
Driving
Amplifier
To Cable

**Figure 1-a**

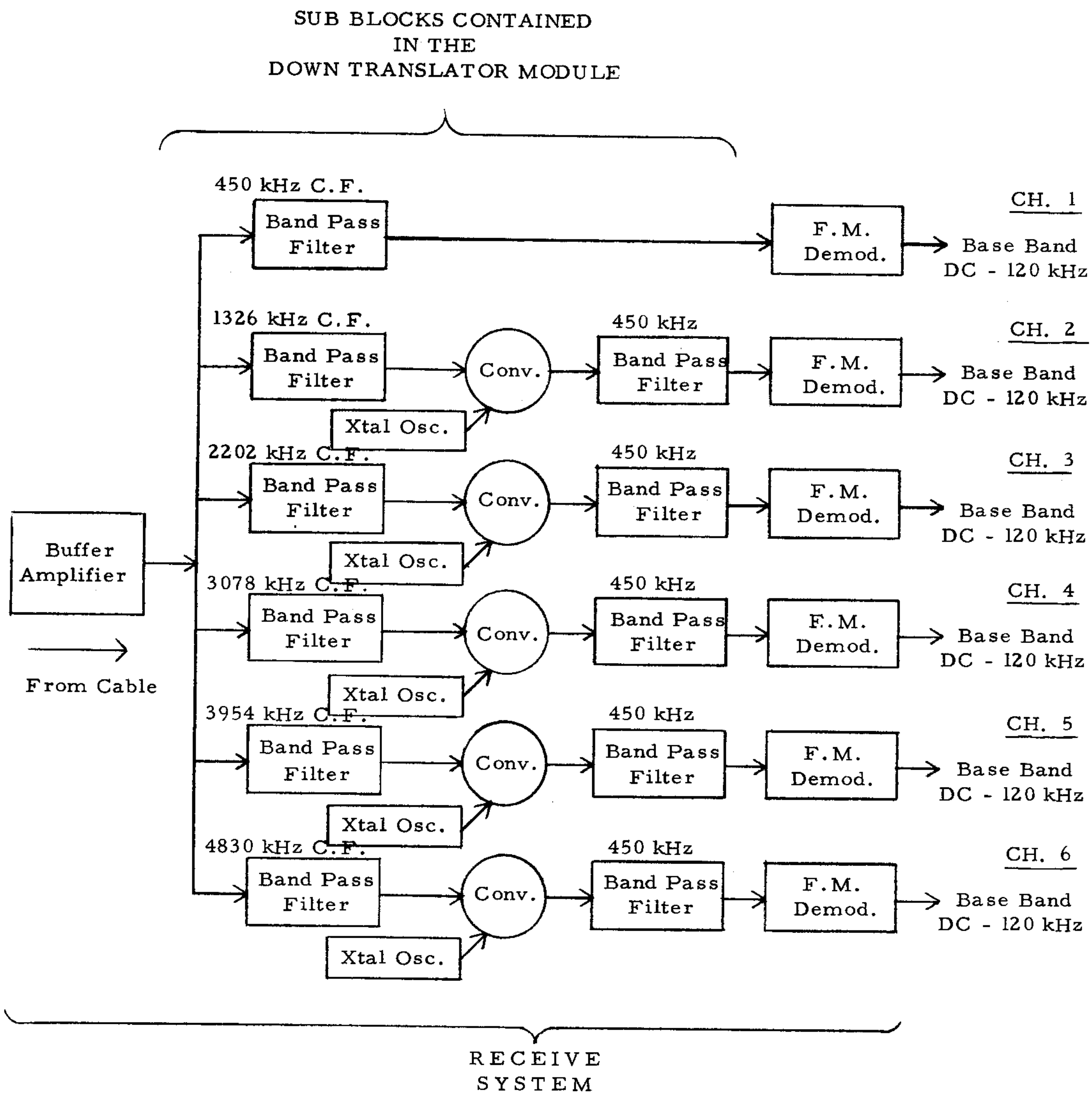

SUB BLOCKS CONTAINED
IN THE
DOWN TRANSLATOR MODULE
450 kHz C.F.
Band Pass Filter
F.M. Demod.
CH. 1
Base Band
DC - 120 kHz
1326 kHz C.F.
Band Pass Filter
Conv.
450 kHz
Band Pass Filter
F.M. Demod.
CH. 2
Base Band
DC - 120 kHz
Xtal Osc.
2202 kHz C.F.
Band Pass Filter
Conv.
450 kHz
Band Pass Filter
F.M. Demod.
CH. 3
Base Band
DC - 120 kHz
Xtal Osc.
Buffer Amplifier
From Cable
3078 kHz C.F.
Band Pass Filter
Conv.
450 kHz
Band Pass Filter
F.M. Demod.
CH. 4
Base Band
DC - 120 kHz
Xtal Osc.
3954 kHz C.F.
Band Pass Filter
Conv.
450 kHz
Band Pass Filter
F.M. Demod.
CH. 5
Base Band
DC - 120 kHz
Xtal Osc.
4830 kHz C.F.
Band Pass Filter
Conv.
450 kHz
Band Pass Filter
F.M. Demod.
CH. 6
Base Band
DC - 120 kHz
Xtal Osc.
RECEIVE
SYSTEM

**Figure 1-b**

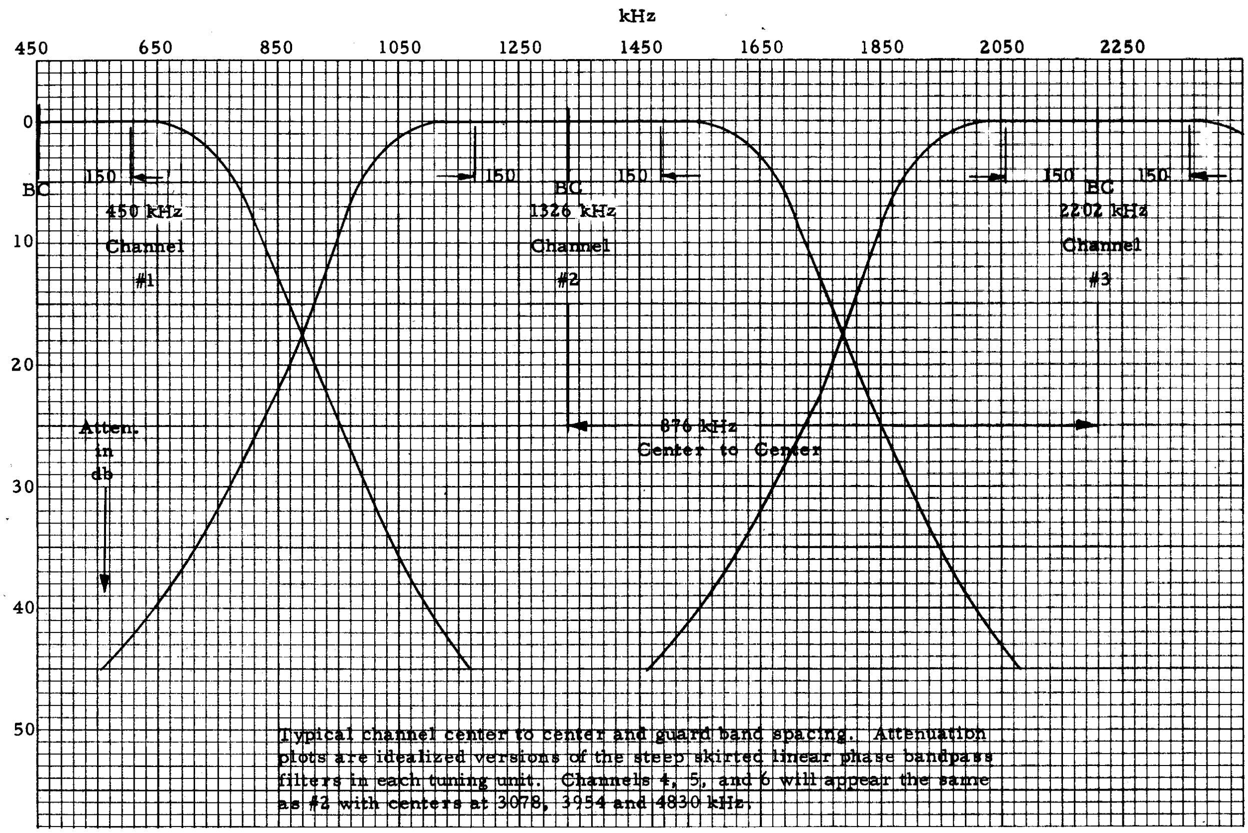
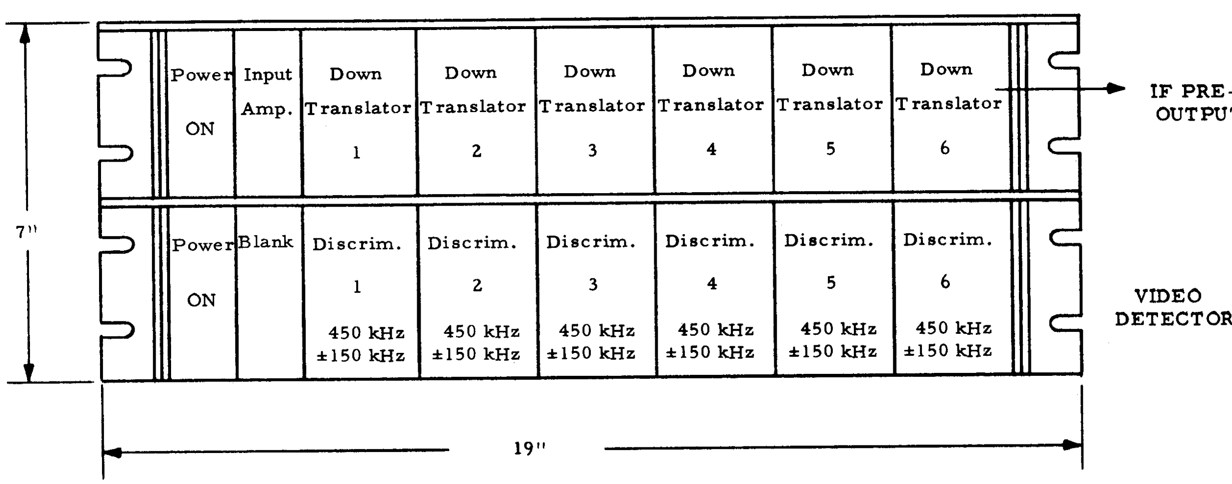



**Figure 2**




Outline of the front panel space required by the end terminal of the line.
The same space is required by the system at the transmit end of the line.

**Figure 3**