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It is the objective of this paper to give CATV managers and technicians alike a better understanding of microwave in general and CARS Band in particular. A secondary objective is to explore the potential uses of CARS Band microwave as an invaluable tool for the CATV operator.

The CATV industry is unique in that it is populated by people with a broad range of backgrounds. Often it is the cable system manager who has had limited experience in microwave that must decide on path lengths and weigh system performance against economics. Therefore I hope no one is offended by the simplicity of the analogies used in this presentation.

In general, microwave is that segment of the radio spectrum above UHF and below light. (Figure 1) The majority of TV microwave in use today is concentrated in the area between 2 and 13 GHz, with some experimental work being done at 18 and 40 GHz.

CARS Band (Community Antenna Relay Service) is that segment of the microwave spectrum from 12.7 to 12.95 GHz. This segment of the spectrum was set aside by the FCC for TV microwave relays operated by cable systems under Part 74 subpart J, Community Antenna Television Relay stations of the FCC rules and regulations. Under this subpart, ten, 25 MHz primary channels were allocated along with nine secondary channels interspaced between the primary channels. Either AM or FM modulated microwave signals may be used with power outputs not to exceed 5 watts. Directional antennas must be displayed with a beam width less than 3°.

Microwave is very similar in characteristics to light. Microwave radiation can be focused into a beam with a parabolic dish or reflected off a billboard which acts as a plate mirror. Just as light is refracted or bent as it moves through media of varying density, microwaves are bent as they move from dense cool air to less dense hot air in an inversion layer. This bending effect is a major contributor to fades. The beam is simply bent out of alignment. Microwave can also be obstructed by solid objects or by fog and rain much the same as clouds attenuate the sunlight.

The microwave carrier can be changed in amplitude or shifted in frequencies by an amount directly related to the video or other intelligence which is transmitted over the beam. A microwave carrier can be likened to another carrier, the railroad. (Figure 2) The video we wish to transmit is like a box of information which we can place on flatcar, the microwave baseband. We can also load on a box of stereo FM and a third box of computer data. The flatcar travels along the carrier and is unloaded at the receiving dock. Information is loaded on a microwave carrier with a modulator and unloaded with a demodulator. Just as a flatcar has size and weight limitations, a microwave baseband has bandwidth and information density limitations.

At the head-end of a CARS system, off-air TV signals are detected as a composite signal consisting of 4.2 MHz of video information along with the 4.5 MHz audio carrier. (Figure 3) This composite signal is modulated directly on the baseband of the microwave at the transmit terminal and delivered to the output of the receive microwave terminal where it is converted up to one of the VHF TV channels. Some microwave systems carry an additional FM subchannel above the TV. Others carry a third channel of data, remote distribution, switching or alarm.

Currently it is practical to diplex all ten of the (primary) CARS Band channels on one antenna system. This is achieved through the use of dual-polarized feeds at the focal point of the parabolic reflectors and highly stable crystal controlled equipment. For example, the odd numbered channels are transmitted in vertical polarization and the even channels are transmitted in horizontal polarization. Figure 4 shows a multi-channel system layout.

The ways in which a CATV operator may utilize CARS Band are far greater than one might first imagine. When we think of CARS Band the first thought that comes to mind is the importation of distant TV, FM, and data signals. More and more we are seeing the CARS Band used in place of a trunk line between the mountain top head-end and the local distribution point down-town.

A CARS Band link can provide 10 simultaneous channels over a single hop and eliminate pole lines, rights-of-way, construction problems and years of pole rental. With the advent of 100 percent solid state modular microwave, the maintenance associated with a ten channel microwave system is not substantially different than an equivalent number of trunk line amplifiers.

The terminals of a microwave system are usually located in an air-conditioned building, where test equipment and facilities are readily available. A trunk line is subject to icing, salt air corrosion, and other destructive forces. Moreover, the line amplifiers must be maintained in this environment. A well-designed CARS Band microwave system is no more susceptible to outages than a buried cable.

On paths of ten miles or more, the cost of a microwave system and trunk system is very competitive. But most important, the signals on a microwave system can be delivered from the mountain top to down-town in perfect condition. Differential phase and gain will be less than 1° and 1 dB respectively on the microwave system.

CARS Band microwave also makes it convenient to construct the local distribution point at the geographical center of the community. Trunk lines can be constructed like the spokes on a wheel. This type of system offers shorter trunk lines, lower construction and maintenance costs along with a more uniform picture to all subcarriers. If a main trunk line fails, it affects only a pie section of the city and not the entire system.

Economics is always a key consideration in the determination of whether it is practical to provide CATV service to a given community. Often the investment in a single high-quality head-end can be distributed among several communities by splitting the output of the CARS Band microwave system and directing this split signal to a microwave receiver located in these communities. Small nearby communities which cannot afford an adequate head-end can take advantage of a common CARS Band feed. (Figure 5)

Another potential application for CARS Band which is in accordance with FCC policy but in conflict with letter of FCC law at this time is local origination. Potentially, CARS Band could be utilized for head-end studio, or remote pickup links to originate on-location community affairs, educational, and entertainment programming. As you are all aware, yesterday's news is history. Live color coverage of controversial city council meetings, today's sporting events, and local news can develop community spirit and subscriber hook-ups.

Historically, the state of the art has not made 13 GHz remote pick-up equipment too practical. At these frequencies, microphonics, frequency instability, and temperature sensitivity have often times made a TV remote into an ordeal. Today's crystal-controlled total solid-state portable units have made such remotes an everyday occurrence in the broadcast industry. For example, the network coverage of the Democratic Convention in Chicago and also the coverage of the Kennedy funeral train from New York to Washington, D. C. was accomplished in the 13 GHz region. The wireless backpack color cameras used at the Mexico Olympics were operated in the CARS Band frequency region.

The question most asked by a prospective CARS Band user is "How far can I reliably transmit?" If you ask two experts, you will likely get two answers. CARS Band is a relatively new frontier and there is a limited history of operation in this band. Experience in the last few years indicates that the initial gloomy outlook was somewhat pessimistic.

I think the best way to understand the range limitations of any microwave system is to evaluate a system. Figure 6A shows a CARS system over a 20 mile path and Figure 6B shows a similar system over a 40 mile path. Each system has approximately a 40 dB fade margin which relates to a 99.99 percent reliability.

Figure 7 shows the video signal-to-noise versus signal input to the CARS Band receiver. Fade margin is the difference between the signal received under ideal conditions and the minimum signal input necessary to produce an acceptable picture.

If the fade margin is divided into the path length, the 20 mile path can withstand 2 dB per mile of rain attenuation while the 40 mile path fails with only 1 dB per mile of attenuation.

On the 40 mile path, performance can be improved by using a transmitter which is 10 times as powerful as the first. This gives a 50 dB fade margin, but only 1.25 dB per mile safety margin. At the same time, overall system reliability may be reduced by using high voltage power supplies and high power transmitting devices which are less reliable than a system working at moderate power levels. Larger antennas, such as 10 food dishes, would add another 4 dB to the system fade margin, but when this is distributed over a 40 mile path, it does little to help the system reliability. Also consider that a 10 foot dish concentrates the microwave beam into a narrow sliver only 0.5° wide. A slight atmospheric bending can move the beam off the receive dish. Mechanical stability of the dishes becomes a significant problem when the beam is this narrow.

Therefore, there must be a point of diminishing returns where bigger dishes and more powerful transmitters no longer improve the basic system reliability. This point seems to occur over path lengths between 20 and 30 miles long. Beyond this point, it becomes a value judgment on the part of all concerned whether an occasional outage warrants the expense of another repeater system. In dry mountain areas where turbulence keeps the air homogenized, 60 mile paths have been found to be as reliable as a 15 mile path in flat lands where the air stagnates and inversions are common.

Figure 8 shows the relative effect moisture will have on path attenuation. Maps such as Figure 9 can help determine the effect local weather might have on a particular path. The experience of other microwave users in your area at lower frequencies is an invaluable indication of your potential success at CARS Band. If you factor-in rain attenuation based on local weather, success at CARS Band will follow very closely the success of neighboring 7 or 11 GHz systems.

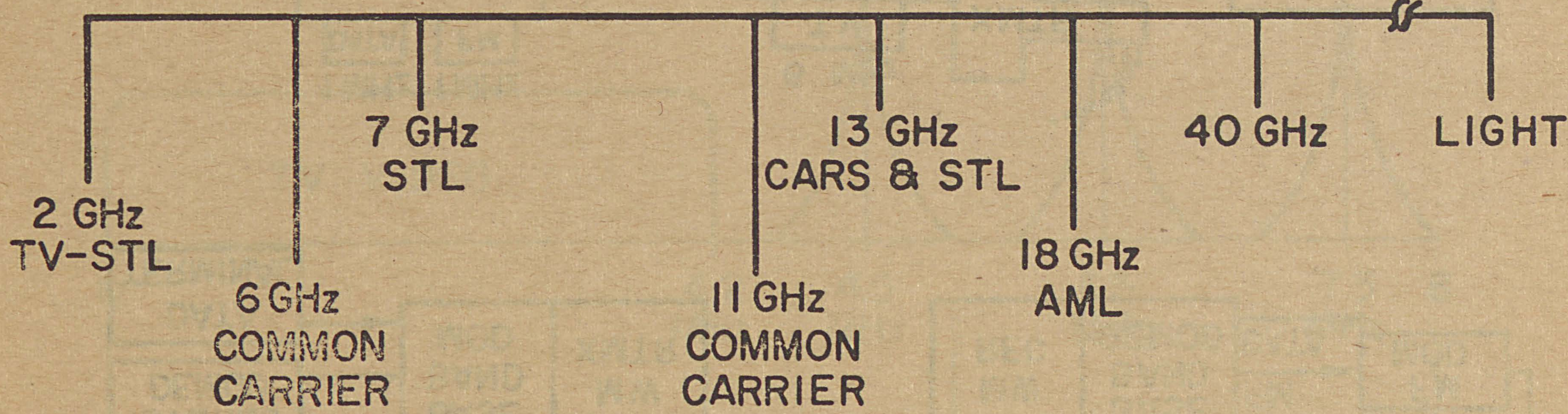

2 GHz
TV-STL
6 GHz
COMMON
CARRIER
7 GHz
STL
11 GHz
COMMON
CARRIER
13 GHz
CARS & STL
18 GHz
AML
40 GHz
LIGHT

Figure 1

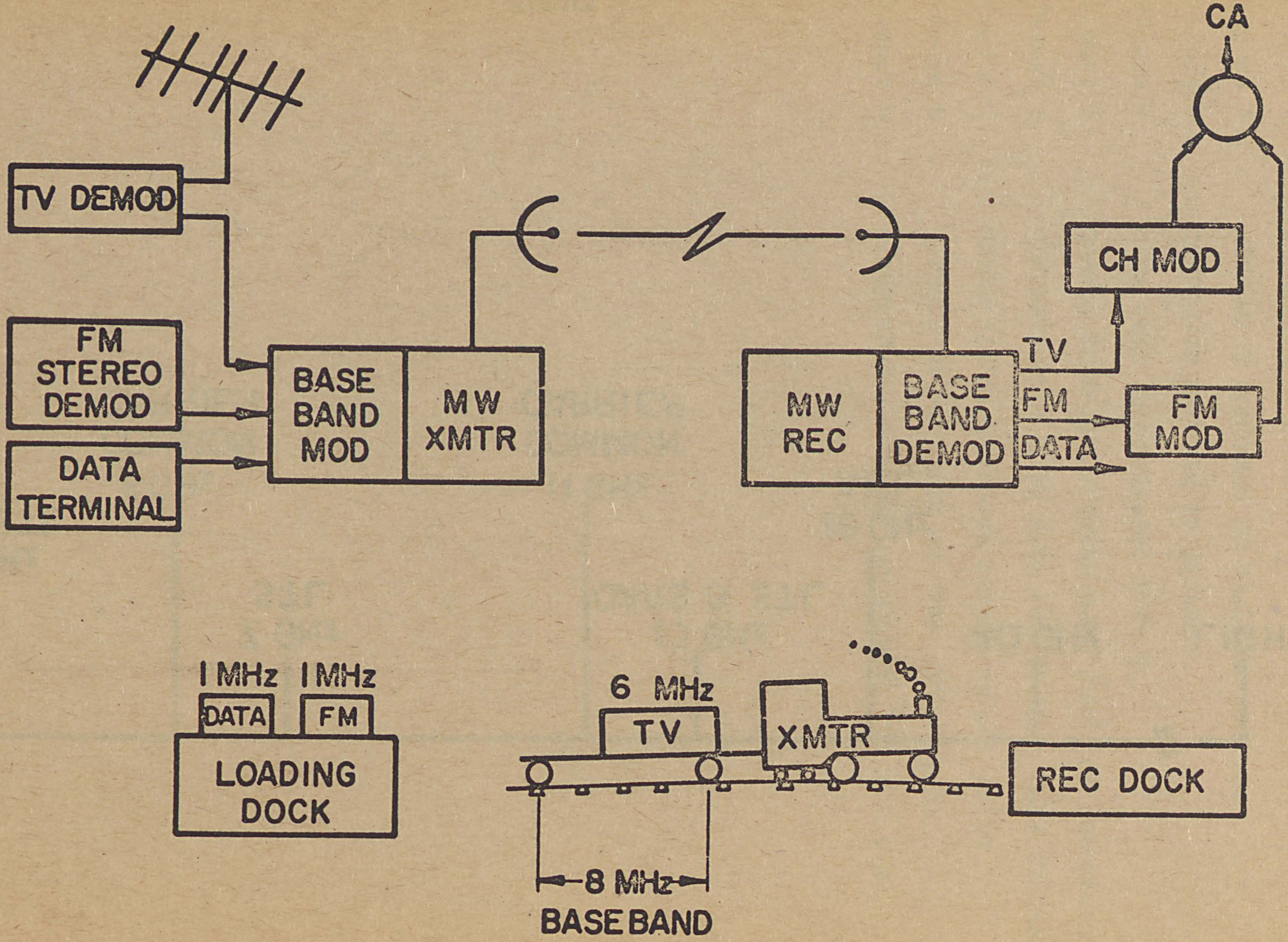

CA
TV DEMOD
FM STEREO DEMOD
DATA TERMINAL
BASE BAND MOD
MW XMTR
MW REC
BASE BAND DEMOD
TV
FM
DATA
CH MOD
FM MOD
1 MHz
1 MHz
DATA
FM
LOADING DOCK
6 MHz
TV
XMTR
REC DOCK
8 MHz
BASEBAND

Figure 2

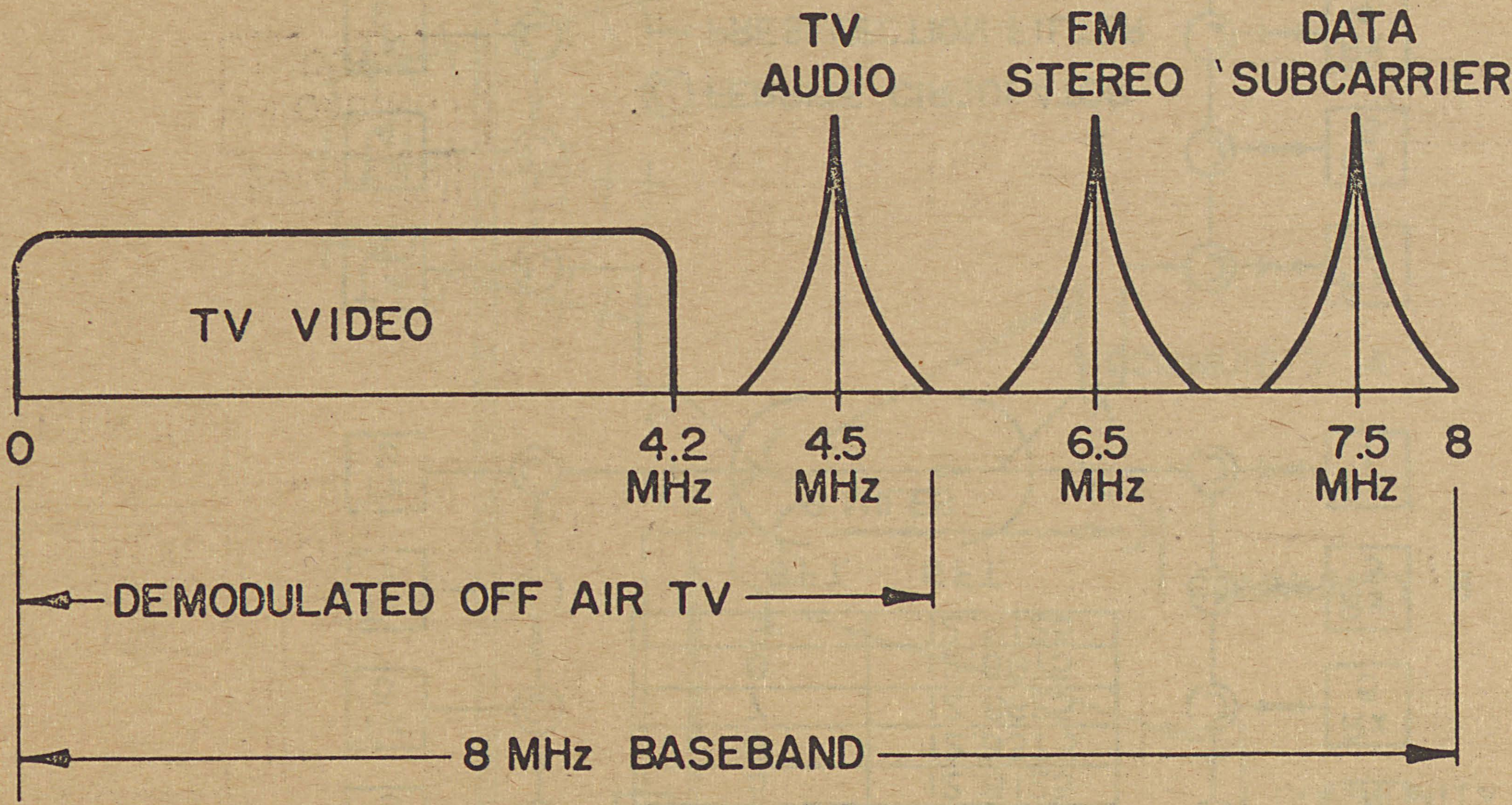
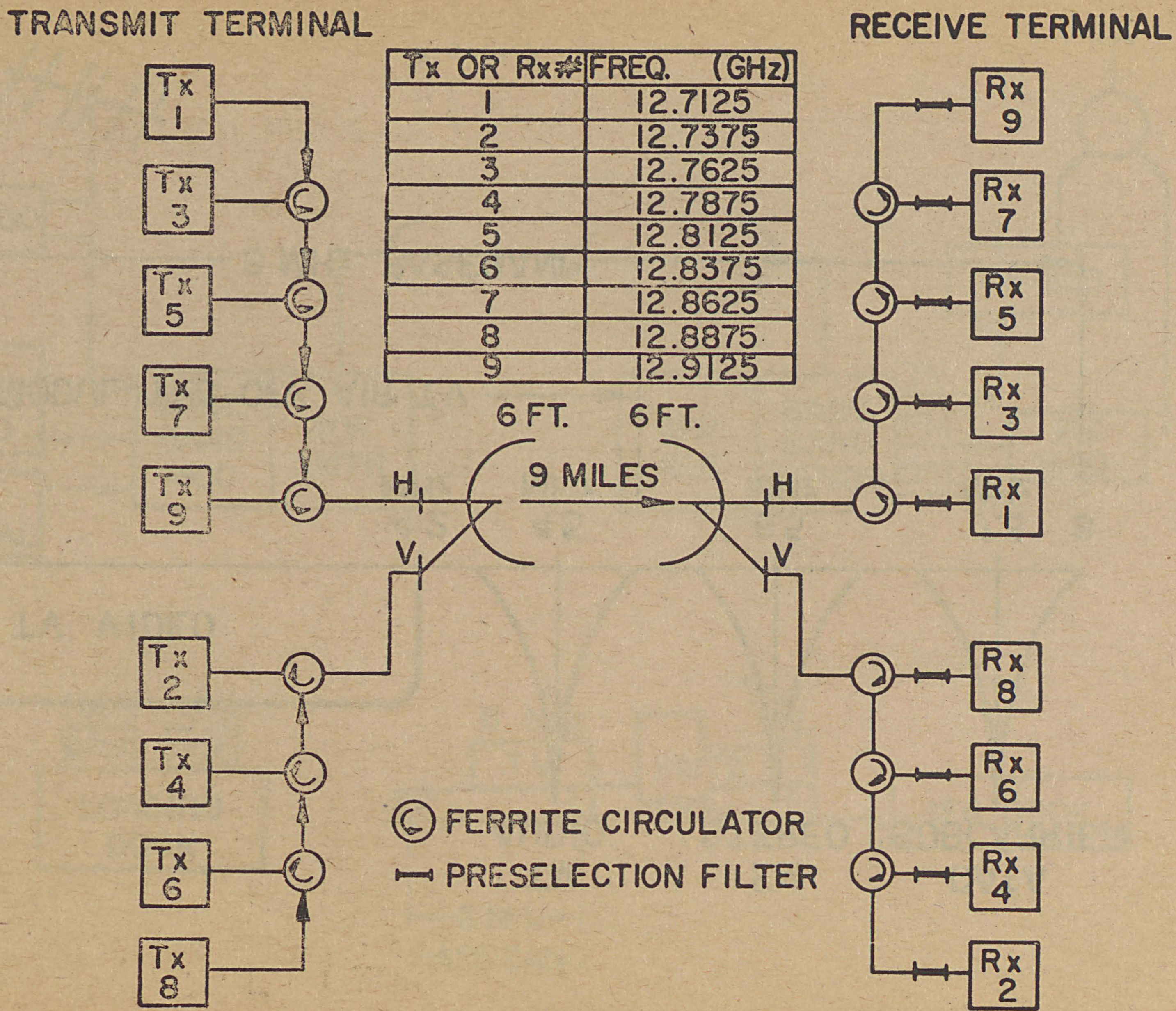
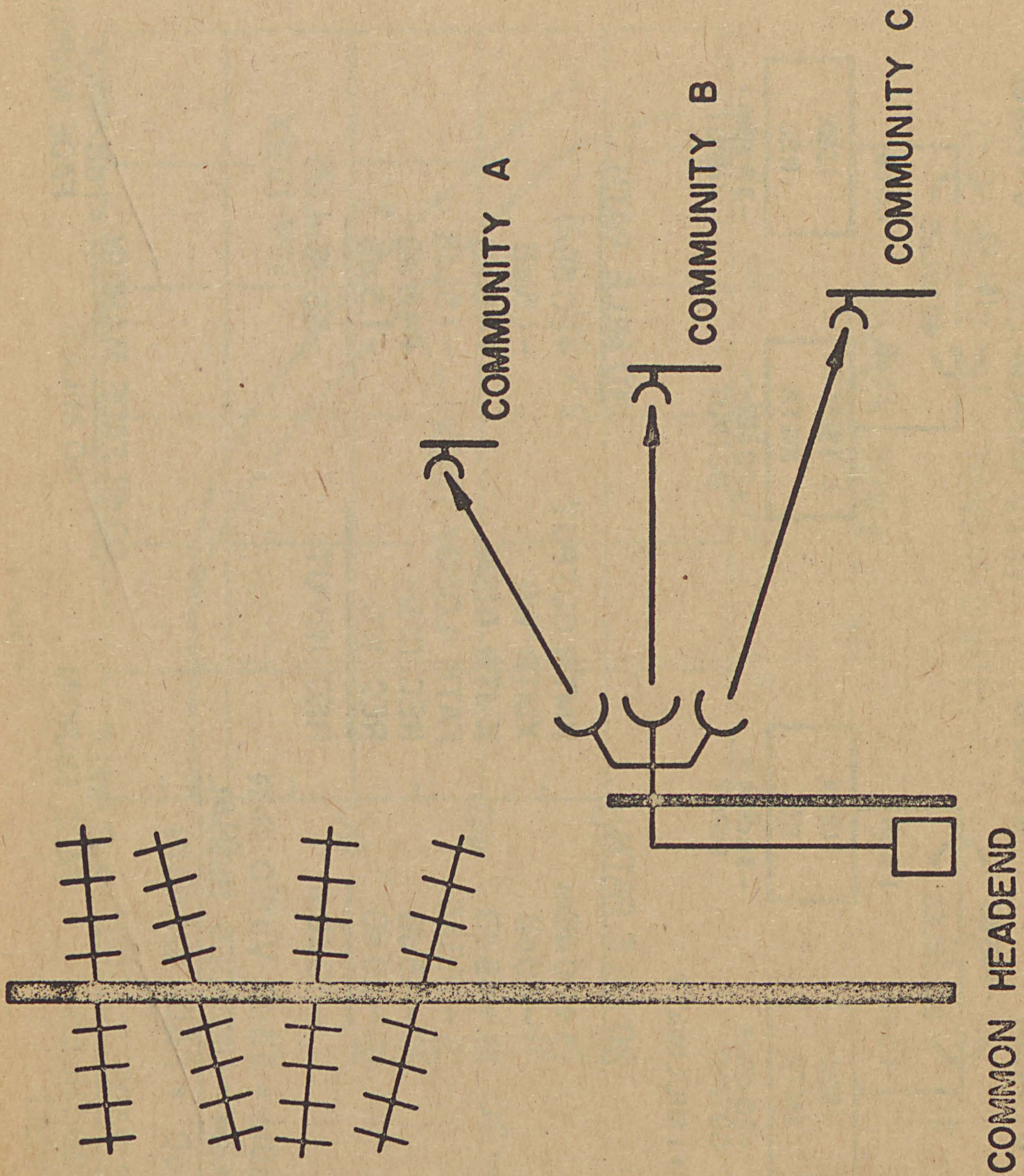

TV
AUDIO
FM
STEREO
DATA
SUBCARRIER
TV VIDEO
0
4.2
MHz
4.5
MHz
6.5
MHz
7.5
MHz
8
DEMODULATED OFF AIR TV
8 MHz BASEBAND

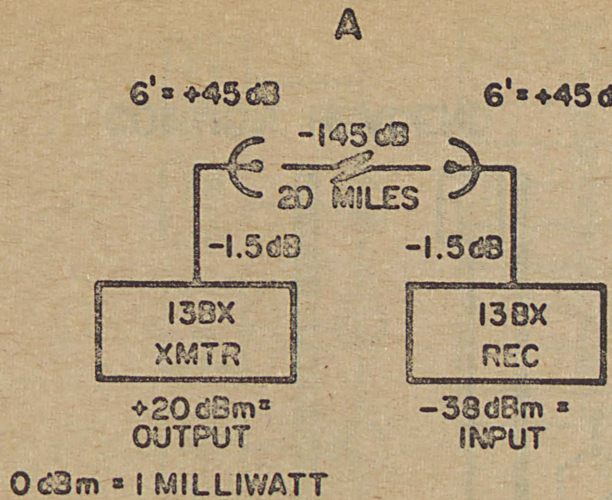
Figure 3

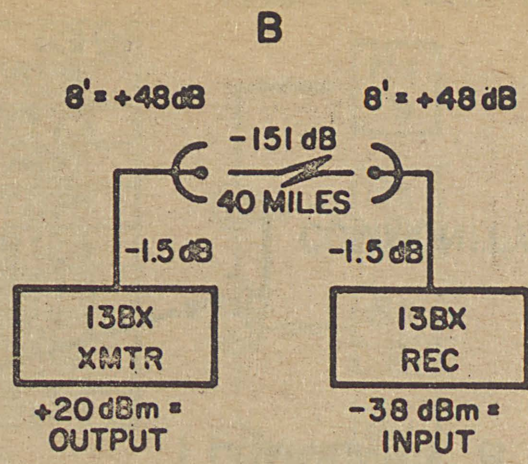


Tx OR Rx #	FREQ. (GHz)
1	12.7125
2	12.7375
3	12.7625
4	12.7875
5	12.8125
6	12.8375
7	12.8625
8	12.8875
9	12.9125

Figure 4


COMMUNITY A
COMMUNITY B
COMMUNITY C
COMMON HEADEND





20 MILE PATH		40 MILE PATH
+20 dBm	XMTR OUTPUT	+20 dBm
-1.5 dB	XMTR WG	-1.5 dB
+45 dB	XMTR DISH	+48 dB
-145 dB	PATH LOSS	-151 dB
-45 dB	REC DISH	+48 dB
-1.5 dB	REC WG	-1.5 dB
-38 dBm	REC INPUT	-38 dBm

-78 dBm = 33 dB VIDEO S/N
-38 dBm = UNFADED SIGNAL
40 dB = FADE MARGIN

$\frac{\text{40 dB FADE MARGIN}}{\text{20 MILES}}$ = 2 dB/MILE FADE MARGIN

$\frac{\text{40 dB FADE MARGIN}}{\text{40 MILES}}$ = 1 dB/MILE FADE MARGIN

Figure 6

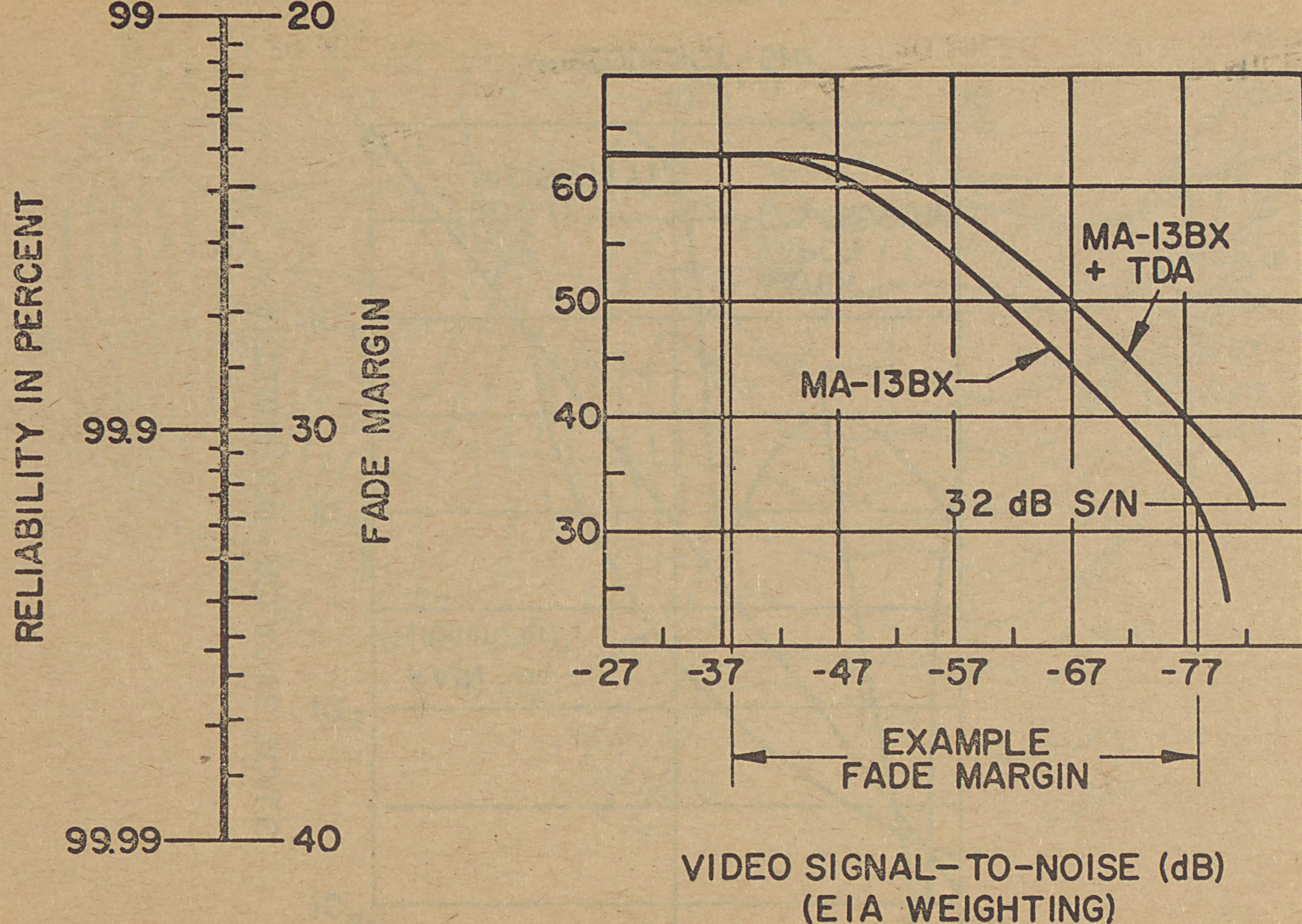

RELIABILITY IN PERCENT
99
99.9
99.99
20
30
40
FADE MARGIN
60
50
40
30
MA-13BX
+ TDA
MA-13BX
32 dB S/N
-27
-37
-47
-57
-67
-77
EXAMPLE
FADE MARGIN
VIDEO SIGNAL—TO—NOISE (dB)
(EIA WEIGHTING)

Figure 7

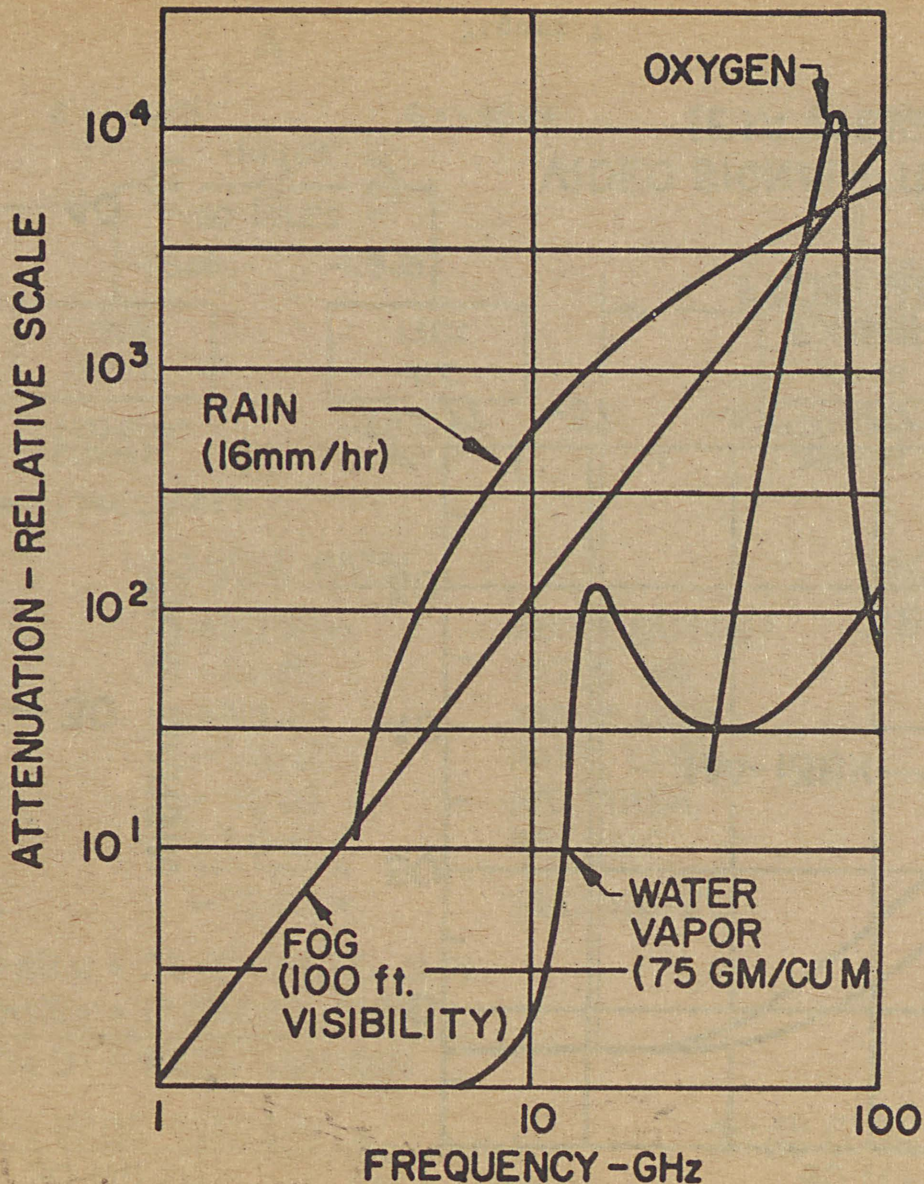

OXYGEN
RAIN
(16mm/hr)
FOG
(100 ft.
VISIBILITY)
WATER
VAPOR
(75 GM/CU M
ATTENUATION - RELATIVE SCALE
10^4
10^3
10^2
10^1
1
10
100
FREQUENCY - GHz

Figure 8

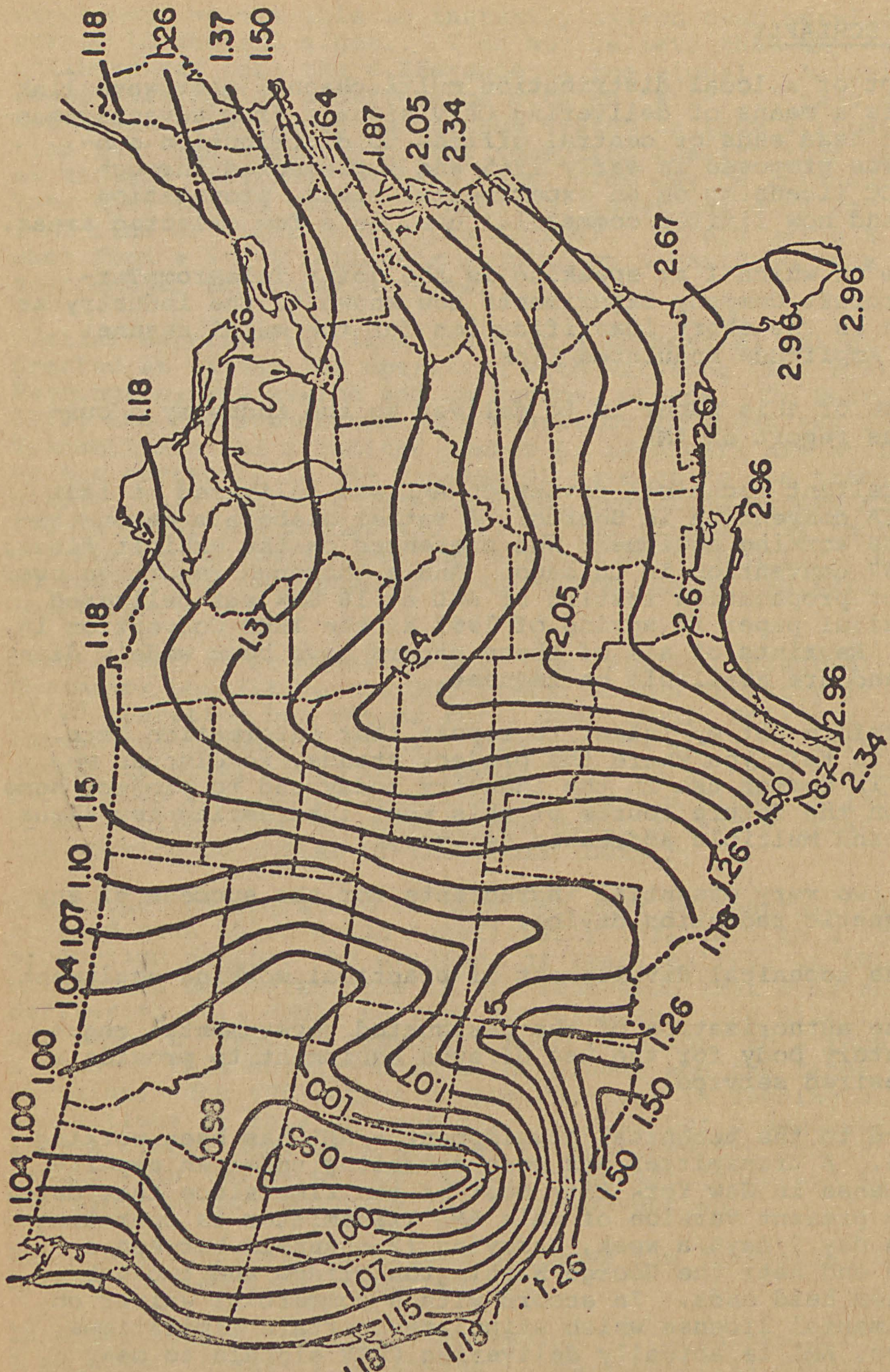

1.18
1.26
1.37
1.50
1.64
1.87
2.05
2.34
2.67
2.96
1.15
1.10
1.07
1.04
1.00
0.98
0.95

Figure 9