LOW COST CARS BAND MICROWAVE SYSTEMS

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ABSTRACT

This paper summarizes the efforts expended by Microwave Associates, Inc. during the past year resulting in the design and placing into production a line of compact CARS band FM microwave receivers and transmitters using cost effective techniques borrowed from those used by the Company in mass producing microwave Gunn diode RF powered transceivers for the police radar and intrusion alarm markets. The compact new CARS band units, produced at a fraction of the cost of traditional designs, also rely heavily on the latest linear and digital integrated circuits which have appeared on the market during the past two years. The paper covers both digital and analogue methods of stabilizing Gunn diode oscillators that are compatible with high quality video modulation. The authors also discuss both the technical and cost considerations of systems interfacing with TVRO terminals and CATV head ends incorporating these new designs.

BACKGROUND

Traditionally, CATV operators have been using microwaves to import channels from other areas by locating a directional TV antenna at some strategic high point,and bringing in its received signals by as many as five hops of either private or common carrier microwave to the cable head end. This particular use of microwaves remains important but it is also now possible to bring in channels considered high quality from both a technical and entertainment point of view via a satellite receive-only terminal for a relatively modest investment. It is estimated that there are as many as 200 such terminals in operation today.

TODAY'S CATV SYSTEMS

The typical 1978 CATV network may well be a hybrid one combining perhaps four imported channels using up to two hops of microwave such as the low cost units to be described in this paper, a TVRO terminal located in a site which may or may not use some low cost microwave to transport say three satellite-receive channels to the operator's head end and possibly up to two hops to couple the TVRO output to other head ends either owned by the operator or cost-shared by operators in readily accessible adjacent towns. Figure (1) is one possible arrangement. The typical 1978 network will also have up to three channels involving local origin of some sort. For all the above uses, the selection of microwave vs. cable vs.

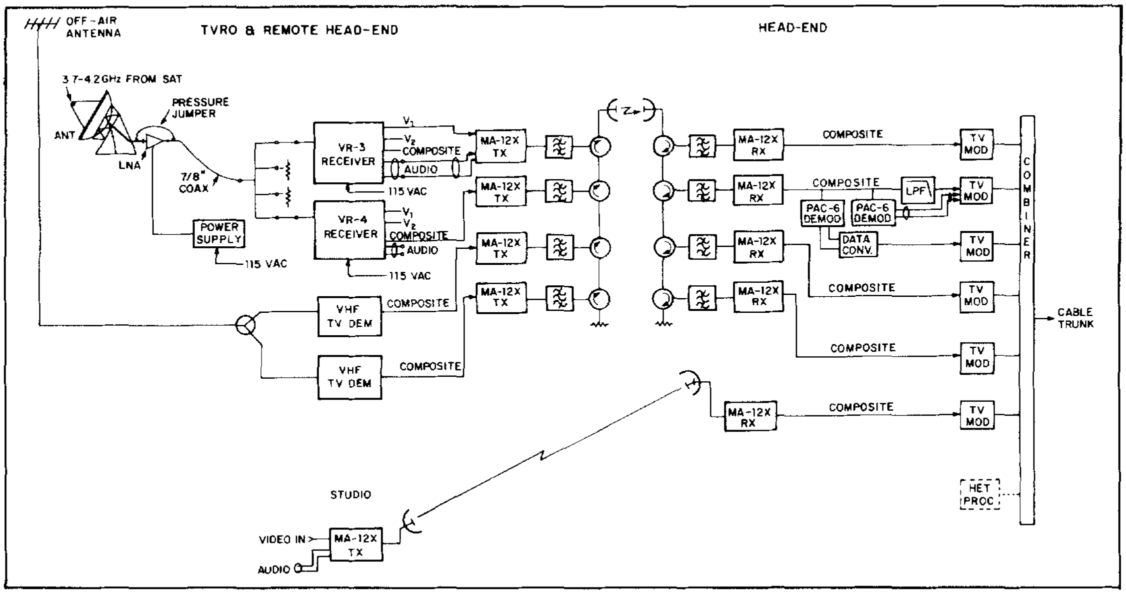

FIGURE 1. A TYPICAL 1978 CATV NETWORK

common carrier will be particularly sensitive to the cost trade-offs involved. If lakes, rivers, expensive real estate, or any area with a high political/red tape content must be bridged, the low cost microwave system will probably win out. Cables over short distances, where a large number of channels are involved, will probably be the method of choice in flat farmland or its equivalent.

In recent years, amplitude-modulated microwaves have been used extensively with systems involving up to 40 channels. Systems with fewer channel requirements such as found in rural areas are generally attracted to the low cost FM systems described in this paper. FM systems also offer an advantage in regions of frequent heavy rainfall, purely due to the greater fade margins.

LOW COST MICROWAVE DEFINED

The authors have chosen to identify the term "low cost microwave"(1)(2) with the rather large grouping of commercial microwave components and subsystems which have mushroomed in volume in the past five years and are generally associated with police radar, intrusion alarms, sensors for door openers, etc. All of these subsystems have one common technology in that they rely on the use of one or more small gallium arsenide Gunn diodes. J. B. Gunn, a member of the IBM technical staff, invented the diode that bears his name in the middle sixties. This tiny device has the property that when mounted in a small resonant cavity and powered by approximately 10 volts of DC, the DC is converted directly into useful readily modulated microwave energy. For several years, these Gunn diode oscillators have been also used as local oscillators in microwave super-heterodyne receivers in more sophisticated systems. Their use in communications systems up until a year ago has been somewhat limited due to their general tendency to drift downward in frequency with increase in temperature, thus requiring an oven for stable performance.

THE TRANSMITTER

During the past year, economical phase-locked Gunn oscillator circuits have been developed. Figure (2) shows a cutaway of a Gunn oscillator from an MA-12XC transmitter suitable for FM video modulation. Using cheap external circuits, this unit can be phase-locked to a crystal to achieve stability over wide temperature ranges.

As can be seen, the cutaway shows three separate resonant cavities interconnected by variable iris couplers. The left hand cavity with a large flange contains the basic Gunn oscillator and a gallium arsenide tuning varactor accessible electrically from both sides. All interconnections to the diodes are through cylindrical RF chokes with the ability to pass DC and modulating voltage but presenting a high impedance, hence isolation to microwave energy. The small white ceramic cylinders seen in the upper portion of the left and right hand cavities are

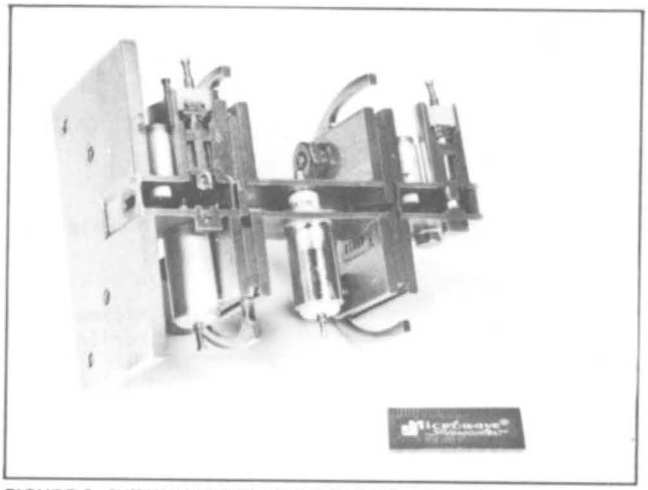

FIGURE 2. CUTAWAY OF 12XC GUNN OSCILLATOR/ AFC ASSEMBLY

used for mechanical tuning. In this unit, while most of the oscillator energy is coupled to the load (antenna) through the flange/iris combination on the extreme left, the smaller iris in the back of the oscillator cavity feeds a fraction of the energy to a Schottky mixer diode in the center cavity. The third cavity on the right hand containing a multiplier-type varactor diode is coupled to the right hand end of the mixer cavity. This varactor diode is driven by approximately 15 milliwatts at 200 MHz. The 200 MHz is generated by 100 MHz overtone crystal oscillator which drives a transistor doubler. When this 200 MHz energy impacts the varactor, a spectrum of microwave energy is generated with comb lines separated by 200 MHz. The oscillator cavity is mechanically adjusted to provide a signal which, say 12.75 GHz, when mixed with one of these lines, for instance 12.8 GHz, produces heterodyne signal at approximately 50 MHz. This 50 MHz signal passes through a limiter-preamplifier and then is divided down to 6.5 KHz by several very economical integrated circuit divider circuits. Similarly, an 8 MHz "reference" crystal is subdivided to 6.5 KHz. The two 6.5 KHz signals are then applied to a low cost IC which performs as a phase comparator. The DC error output of the comparator is fed back to the gallium arsenide tuning varactor in the Gunn diode oscillator which varies the VCO frequency until the oscillator "locks up" at 12.75 GHz. The low comparison frequency has been selected to allow the tuning varactor to receive simultaneously video modulation, the AFC error voltage and an adjustable DC voltage for manually tuning the oscillator. This phase-locking technique, standard for years at lower frequencies, can now be accomplished at microwaves since all of the components used have been produced in large quantities to serve other non-microwave markets thus greatly decreasing their cost even before applying the incremental volume leverage which must accrue when more of these oscillators are used in microwave communications systems and for CATV.

The frequency stability in the 12.7 - 12.95 GHz region using the phase-locking technique described, provides better than ±.005% frequency stability. The stability is primarily a function of the drift with temperature of the reference crystal and the 100 MHz overtone crystal used in the multiplier driver. Without subjecting the audience to all the technical details, Microwave Associates is now developing techniques which will greatly decrease the inherent temperature drift by introducing into the cavity materials with compensating properties. Further, a new family of hyperabrupt, low loss gallium arsenide tuning varactors is in the advanced stage of development which will greatly increase the linearity of these oscillators under modulation even when subjected to the type of temperature excursions experienced in outdoor mounting of the transmitter.

Figure (3) is a block diagram of the current production model MA-12XC transmitter. In addition to showing schematically information just described, it shows how the output of the oscillator is coupled through an isolator/filter combination to the antenna feed providing a minimum output of +13 dBm. The digital AFC/video block illustrates the interconnections with the AFC module. The unit is powered by 110 V 60 Hz supply consuming approximately 30 watts of power providing +18 V, +9.5 V and +5 V DC for the operating circuits. This particular block shows video with 525 line pre-emphasis. The MA-12EU model operates on 220 V/ 50 Hz mains and provides pre-emphasis for the European 625 line system. The video modulating amplifier uses readily available linear ICs. There is an optional input for 600 ohm balanced audio to provide 4.5 MHz aural subcarrier with the same modulation characteristics as broadcast TV plant. Other subcarrier frequency options are also available with the flexibility of operation with the new MA PAC-6 subcarrier demodulator.

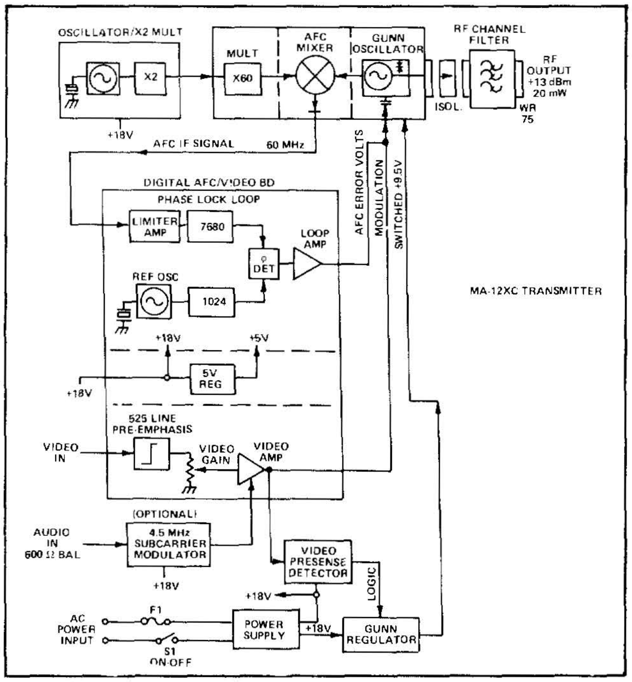

FIGURE 3

In the past, the cable operator has always brought in TV signals formatted in NTSC vestigial sideband AM with FM audio and was only faced with the problem of converting the received AM channel to the desired AM cable channel; however, today's FM satellite signals present a different problem. Here the satellite receiver such as the low cost VR-3 and VR-4 demodulates the FM microwave carrier and provides either a composite base band or separate video and audio outputs. Composite base band in this case is a combination of the standard video signal plus a 6.8 MHz FM subcarrier which is carrying the audio program information as opposed to the traditional 4.5 MHz subcarrier. When interfacing with a standard TV cable modulator, the separate audio and video outputs from the microwave receiver should be used. When interfacing with a FM microwave terrestrial link, then the composite output from the satellite receiver may be fed directly into the microwave transmitter, provided that video and audio components are separated at the FM receiver terminal before they are fed to the cable modulator.

A video presence detector with automatic transmitter turn-off is also included to meet FCC regulations. The MA-12XC has been type-accepted for CARS band and other uses. This small compact transmitter, shown in Figure (4), designed to sell at one third the price of other Microwave Associates CARS band transmitters, should be considered as a real alternative to cable or the use of common carrier services.

FIGURE 4

THE RECEIVER

Figure (5) shows the block diagram of the low cost 12XC CARS band receiver which has had wide market acceptance. Referring to the left upper side of the block diagram, the microwave signal from the antenna is connected by waveguide to the receiver mixer-VCO module via a bandpass filter/ ferrite isolator combination. For most U.S. CATV systems, the RF pass band is 25 MHz. The mixer-VCO assembly is similar in construction to the cutaway of the RF assembly shown for the 12XC transmitter but is less complex since two rather than three cavities are involved. The received signal is mixed in a Schottky diode operated at approximately 1 milliwatt of energy derived through a variable iris at the rear of the mixer from the Gunn VCO. The VCO is mechanically tuned

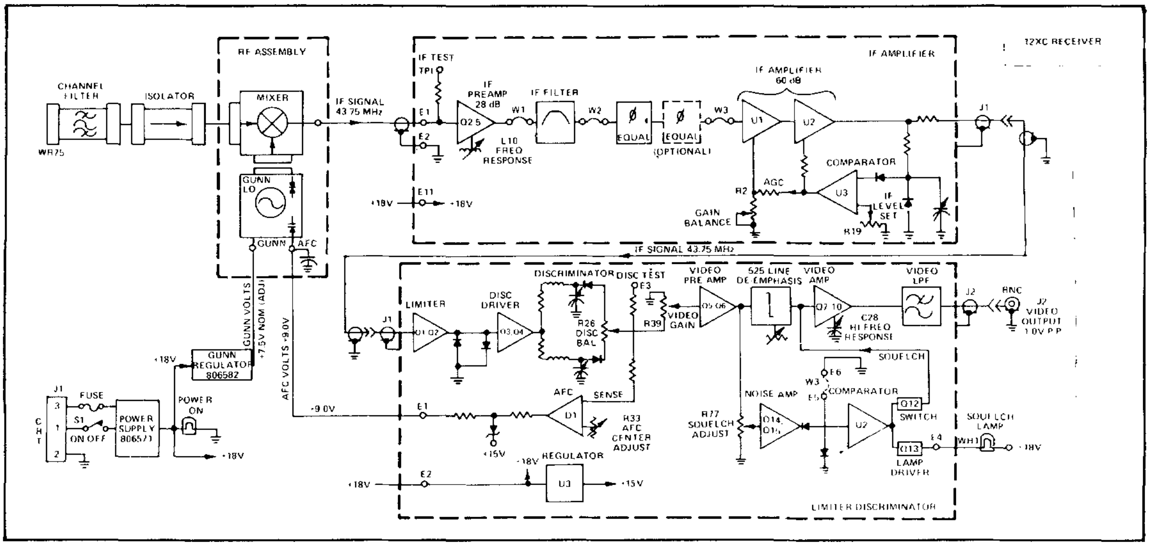

FIGURE 5

to provide an IF output from the mixer at 43.75 MHz. The intermediate frequency of 43.75 MHz is compatible both to the current availability of very low cost IC linear amplifiers (which become more expensive at higher frequencies) and with the elimination of possible "birdies" which could occur when multiple 12XC receivers are interconnected together by branching networks. The IF signal is coupled to the IF amplifier module through a low noise FET preamplifier. In the IF module, the IF signal is shaped by an IF filter which defines the noise bandwidth and provides additional adjacent channel rejection, then undergoes at least one stage of group delay equalization before entering 2 stages of IF IC amplification providing 60 dB of gain, controlled by a comparator/AGC IC.

The output of the IF amplifier is fed to the limiter/discriminator module. Here, two stages of hard limiting are provided which drive a discriminator which demodulates the FM signal and provides a base band output. Either 525 or 625 line de-emphasis and a compatible band pass filter are provided as part of the IF amplifier assembly.

Because of the inherent stability of the transmitter, the receiver needs only to provide a simple analogue AFC which is derived from the discriminator output passed through a DC amplifier to the tuning varactor in the VCO assembly. This module also contains the necessary circuitry to squelch the receiver output if no carrier is present. The receiver can be powered by either 110 V AC 60 Hz, or in the case of the 12EU, 220 V 50 Hz. Regulators provide +18 V DC and adjustable 7.5 V DC. The AFC bus operates at +9 V DC.

The 12XC transmitters and receivers were initially offered in compact cast aluminum housings, 8" x 4.5" x 4.7", weighing 6 lbs., shown in Figure (4). Although this package format meets the requirements of many users, we are also planning to offer a radio for the CARS and certain other markets packaged for rack mounting as shown in Figure (6). This arrangement will provide additional accessory circuit flexibility.

The 12XC receiver provides high quality reliable video when used to receive any video modulated stable FM microwave transmitter tuned to the proper frequency. Although many MA-12XC receivers have been sold paired with MA-12XC transmitters, considerably more have been delivered into systems using other transmitters, often in place, both of our own and other companies' manufacture. Frequently, the paths are such that higher power than the 12XC's +13 dBm is required. In this case, the 12XC receiver is often used in systems which rely on the +28 dBm output MA-12G as a primary transmitter source. The CATV operator should always consider the 12XC receiver and transmitter, each for their individual merits, rather than only as a paired 12XC system. It should be noted that as currently manufactured, the MA-12XC receiver provides only a composite video output. Video base band and audio outputs are not provided, hence the interfacing cable modulator must be capable of accepting composite video.

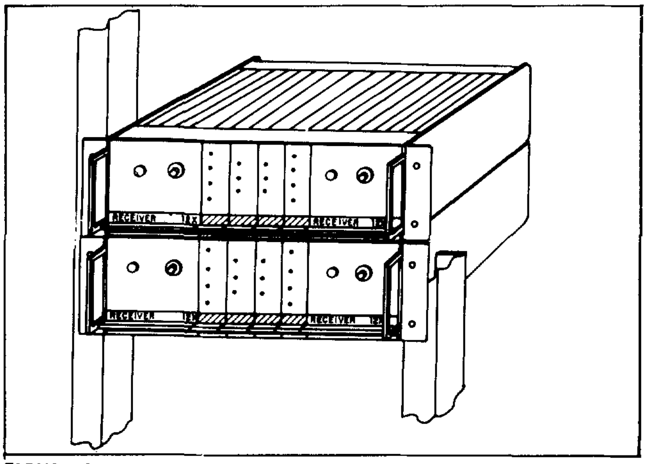

FIGURE 6

SYSTEM ARRANGEMENT

As stated before, this product was launched for the CARS band market and obviously it must provide cost and space effective support for up to twenty channels, as that is the limit under Part 78 of the FCC rules as they apply to FM service. The modular design of the 12XC offered an opportunity to equip 20 go (or return) channels in a single 7'6" (44 unit) rack and still have a few inches to spare. Figure (7) is a photograph of a typical 6-channel receiver rack-up. Figure (8) shows the general arrangement for 20-channel terminals.

Since in the 20 channel (K) Plan both vertical and horizontal polarizations are employed, a convenient and economical branching system was adopted with the upper and lower half of the rack disposed to a common polarization. The problem of combining adjacent off (or even) channels with their 25 MHz separation was solved with hybrid couplers at a slight loss penalty. However, this was offset by lower branching filter losses, with negligible adjacent channel group delay (hence differential phase) contribution. The conventional 3 port circulator combining method was used with waveguide low pass filters in each bus bar (for the ultimate protection against wandering harmonic power). With this arrangement radio equipment can be installed, new channels added, maintenance spares lit up without any on-line "tweeking" for system performance. This is an essential merit for a product of this type, since rarely will the user be equipped with sophisticated microwave line maintenance equipment.

To minimize the system-gain losses, equipment branching position assignments are "flipped" for transmitters and receivers. Figure (9) shows one polarization of a 20 channel hop. Lowest channel transmitters are positioned closest to the antenna port and the mating receiver is the furthest. The worst case total component losses for transmitter and receiver branching add up to 7.4 dB for a 4 channel assembly and 9.8 dB for a 20 channel assembly, all in K Plan. Of course, an additional transmitter rack output port is available for a "free split".

In the CARS band with precipitation effects, the name of the game is fade margin to assure system availability. With the advent of such real time revenue bearers as HBO, repeated circuit outages in the rain belt routes must be avoided. Fade margins of 40 dB (or more) are possible with a complete 12XC system. Recalling the work of Hathaway and Evans, that would set the range of path lengths from about 15 miles in the Mississippi Delta area to about 40 miles in the "L" shaped line joining San Francisco and Montana for a seven hour annual accrued outage. I'm sure we're all familiar with the curves in the Lenkurt Manual[3]

What does this mean as to outside plant with the 12XC? Figure (10) shows a handy fade margin - distance guide for a four channel system,

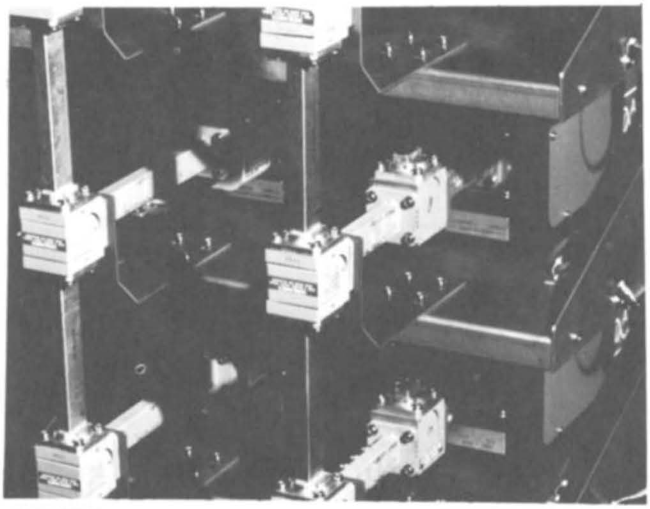

FIGURE 7

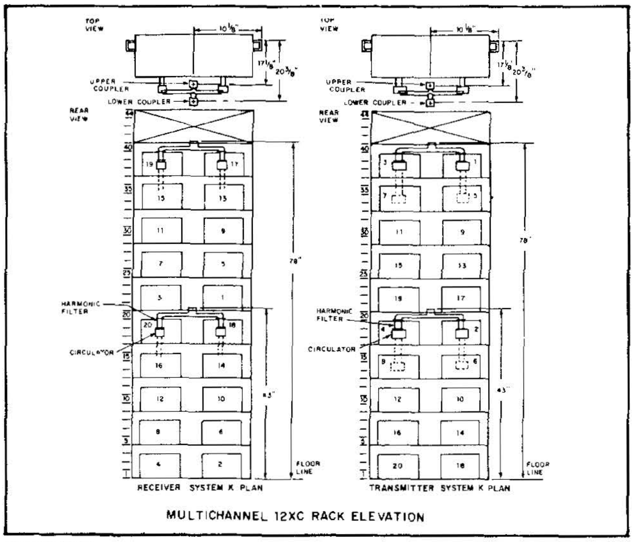

FIGURE 8

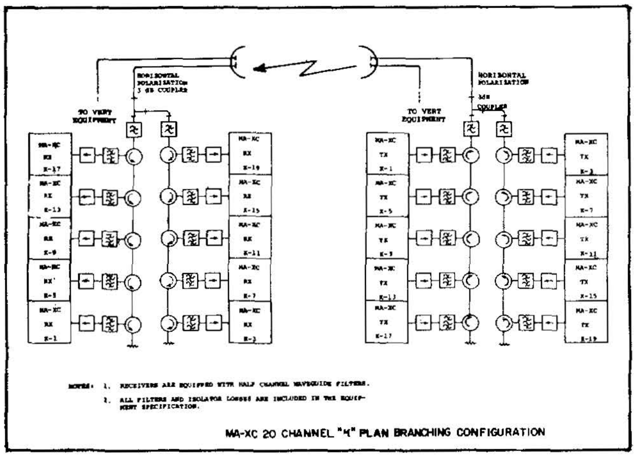

FIGURE 9

and that a pair of 10' dishes will support the 40 dB objective at about 8 miles. Considering that the 12XC receiver sells for about one third the price of conventional receivers, it is only an elementary lesson in economics to consider longer paths, and/or smaller dishes with higher power M/A transmitters (or somebody else's, as the 12XC receiver is a very good listener). Just shift the curves vertically by about 13 dB...or expect 40 dB margin at 25 miles with 10-foot dishes.

The MA-12XC system performance is shown in summary in Figure (11). This clearly indicates that the 12XC system certainly offers a very cost effective solution to many of the CATV operators' microwave problems.

References:

1. "Solid-State Microwave RF Generators"- Ham Radio Magazine, April 1977.
2. "Microwaves for the Masses" - Harlan Howe, Jr. Microwave Systems News, August 1977
3. "Engineering Considerations for Microwave Communications Systems" - GTE Lenkurt Incorporated.

BACK-TO-BACK PERFORMANCE ASSUMING STANDARD CCIR WEIGHTING, A RECEIVER CARRIER LEVEL OF −40 dBm, AND USING 525 LINE TV EMPHASIS

Video Signal-to-Noise P-P to RMS, 4 KHz to 4.5 MHz	55 dB, Minimum
Video Signal-to-Hum P-P to RMS, 10 Hz to 10 KHz	55 dB, Minimum
Differential Gain, 10/50/90% APL	1 dB, Maximum
Differential Phase, 10/50/90% APL	3°, Maximum
2T Pulse "K" Factor	2%, Maximum
Video Frequency Response, 10 KHz to 4.2 MHz	±5 IRE Units
Field Squarewave	3 IRE Units, Maximum
Luminance Chrominance Gain Inequality	6%, Maximum
Luminance Chrominance Phase Inequality	50 ns, Maximum

FIGURE 11. 12XC SYSTEM SPECIFICATIONS

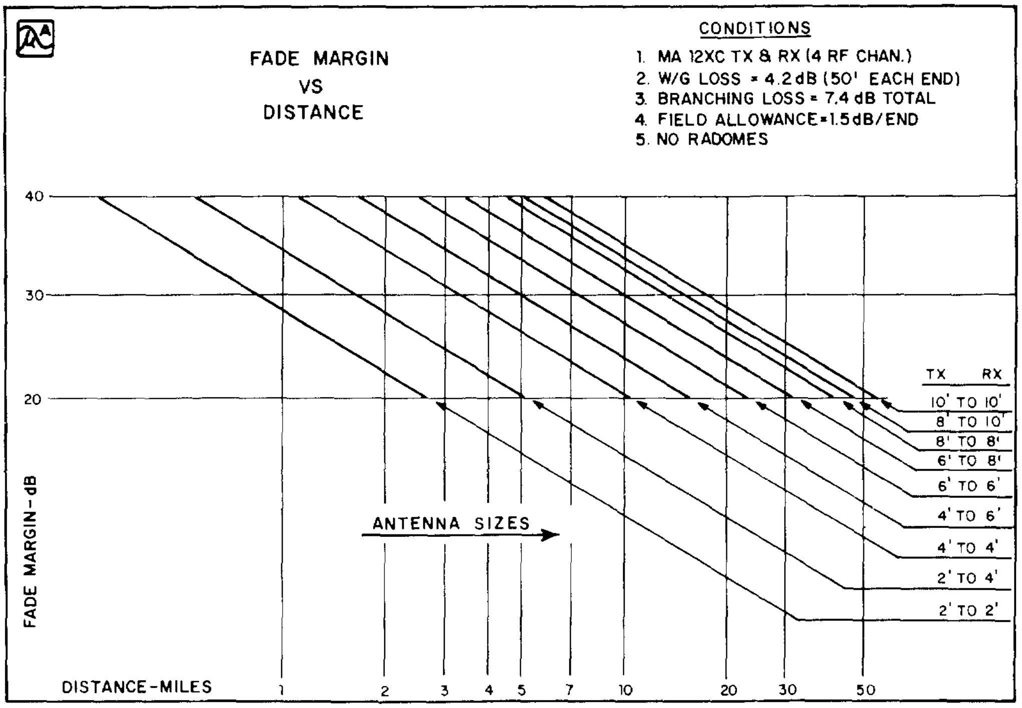

FIGURE 10