A Frequency Agile Receiver for Satellite TV Distribution

COLIN J. R. PALLEMAERTS*
Raytheon Company, Norwood, Mass.

The transmission parameters of a frequency agile receiver for the reception of television from a satellite are calculated and the useful ranges established. The design of a suitable receiver is described. Test data of differential phase, differential gain, and weighted signal-to-noise ratio are presented which show close agreement with the calculated performance. The application for a sync-tip clamper for spreading waveform removal is discussed. The problem of impulse noise when operating near threshold is related and a minimum operating carrier to noise ratio of 11 db is recommended for high performance video systems. From the data presented, the optimum receiver requirements and system performance can be rapidly established for a wide range of satellite system parameters.

I. Introduction

THE distribution of television by a satellite system requires the establishment of a large number of receiving Earth stations located over a vast geographic area. These stations will each serve a local population and will be designed for unattended operation. Each station may be required to receive any of a number of rf channel frequency assignments with the ability of remote frequency control. This requirement results from scheduled transmissions of programs into different geographic time zones, control of commercials, special broadcasts, replacement of failed equipment, etc. All these requirements, and others, require the frequency agility capability of an unattended receiving Earth station.

A TV distribution system consists of a transmitting Earth station, a satellite, and a number of receiving Earth stations. Such a system has been envisioned by others[1,2] as consisting of one or two transmitting Earth stations and up to 300 receiving Earth stations. The number of receiving Earth stations is not limited by equipment design but more likely by the number of available satellite rf channels, and the program distribution problems associated with different geographic time zones, etc. With such a system model the economics of the over-all system are largely affected by the individual receiving Earth station costs. The design of low-cost Earth stations with a flexible configuration for the number of rf carriers to be received with unattended operation is therefore a major economic factor.

Figure 1 is the block diagram of a typical receiving Earth station. The station consists of a 25–32 ft antenna and feed system, a dual uncooled low noise amplifier (LNA), a signal divider, and a number of dual conversion receivers. The dual conversion receivers include video demodulators, baseband, and spreading waveform removal circuitry. The output of the system is a number of clamped video signals at the normal level of 1-v peak-to-peak, each multiplexed with an associated audio subcarrier. As shown, redundancy is provided for the LNA and an additional dual conversion receiver is provided as protection for up to 12 dual conversion receivers.

II. System Parameters

To establish a design objective and range of parameters for the dual conversion receiver it is convenient and practical to subdivide the system parameters into two parts: 1) the over-all system C/T (carrier-to-noise temperature ratio, dbw/°K) and 2) the modulation parameters and used bandwidth. The first parameter C/T which is independent of the modulation characteristics or used bandwidth, is determined by such factors as transmitting Earth station EIRP, satellite receiver G/T (antenna gain-to-noise temperature ratio, db/°K), satellite tramsmitter EIRP, receiving Earth station G/T, up and down link path losses, antenna Earth coverage, etc. However, these variables can be determined and a system C/T derived.

For any given system C/T, the optimum modulation index and receiver threshold bandwidth can be derived for a given video signal-to-noise ratio. As described, the system C/T is a function of the over-all satellite link gains and losses, and the modulation parameters and used bandwidth are a function of the ability of the receiver to recover the modulation signal with a given video signal to noise for the specified system C/T. The performance of the over-all system has been calculated, and the video signal-to-noise ratio vs system C/T is shown in Fig. 2 for several constant values of the carrier to noise ratio (C/N). In this figure the assumptions used are a 525-line TV system employing 525-line CCIR pre-emphasis (PE) with the noise measured in a 4.2-MHz video bandwidth. Monochrome weighting is assumed with the combined weighting improvement for pre-emphasis and monochrome weighting taken as 13 db. The video signal-to-noise ratio is specified as the peak-to-peak composite video signal plus sync, to the weighted rms noise in a 4.2-MHz bandwidth. The carrier deviation is specified as the peak-to-peak value for an input test tone at the pre-emphasis reference frequency of 740 kHz. The parameter C/N is also important in determining the system operating margin above receiver threshold. This margin may be required to accommodate tracking errors, rain attenuation, etc. The carrier deviation used in Fig. 2 is determined by Carsons Rule where receiver bandwidth equals peak-to-peak carrier deviation plus twice the top modulating frequency (4.2 MHz). This is not necessarily the optimum carrier deviation for any specific system but is commonly used as a point of reference. Overdeviation with respect to Carsons Rule can be used and is defined here as the ratio of the actual carrier deviation divided by the Carsons Rule deviation. The use of so-called overdeviations[3] can be applied to Fig. 2 by increasing the video signal-to-noise shown for Carsons Rule by exactly the amount of the overdeviation (db). A practical degree of overdeviation is from 4–10 db, but the limit for any specific system is dependent upon the system characteristics such as group delay, linearity, and spectrum truncation. These transmission deviations may result in increased differential phase and gain of the color subcarrier, baseband

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* Manager, System Design, Radio Relay Engineering Department. Member AIAA.

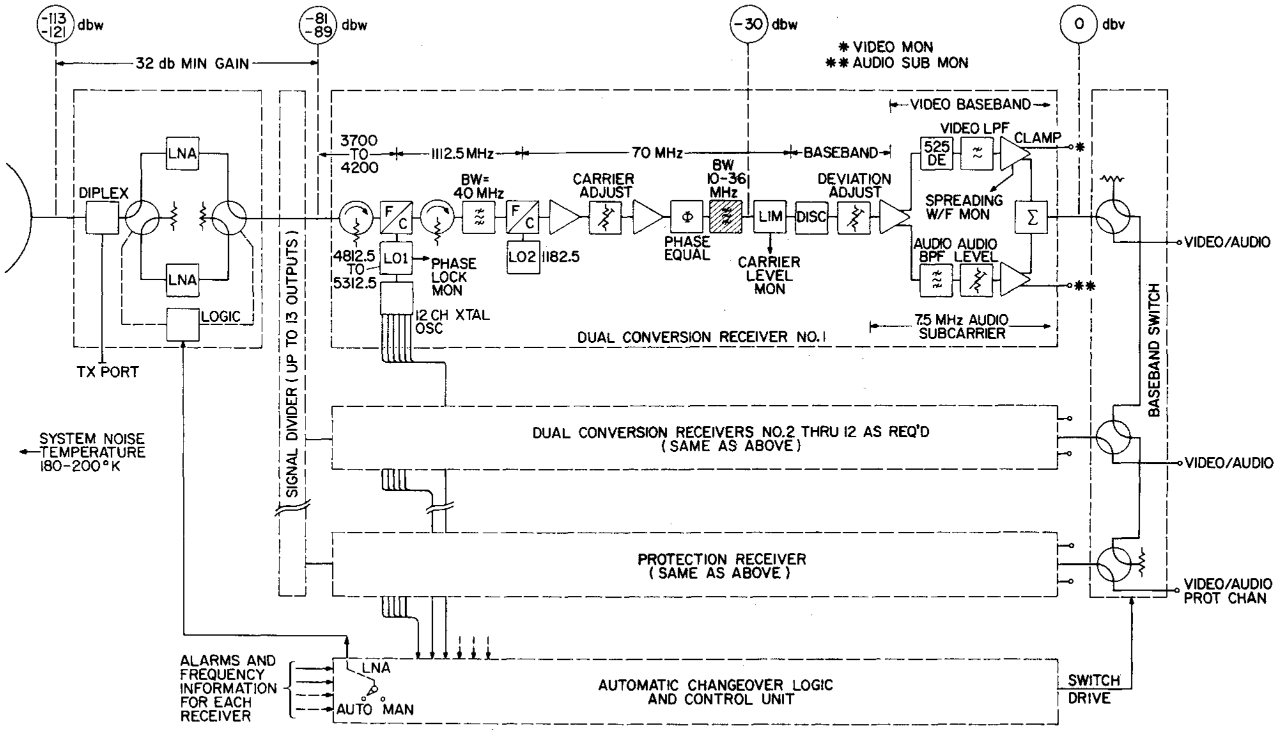


Fig. 1 Earth station block diagram.

response deviations, and video signal distortion. Overdeviation is justified primarily because of the energy distribution of a live video signal over the video signal bandwidth. The energy content of the higher baseband frequencies is relatively low. However, for test patterns, such as a multiburst, this is not the case, and determination of the system characteristics using test pattern generators should be made with Carsons Rule carrier deviation if these are to be meaningful.

Also shown in Fig. 2 are contours of constant receiver bandwidth (based on Carsons Rule). For a practical system, probable limits on the system parameters are assumed as follows. The C/T is minimum to conserve satellite EIRP. The minimum operating C/N is about 11 db, and this provides no system margin. The maximum bandwidth is 40 MHz to maximize the number of rf channels in the rf spectrum. These limits all fall within the dotted boxed area on Fig. 2. As can be seen, the range of useable system parameters for a satellite system is quite small.

III. Dual Conversion Receiver

Receiver Requirements

As has been shown, the range of parameters that can provide a reasonable video performance is limited, and as a result a general purpose dual conversion receiver design can be implemented.

The contributions of the receiver noise temperature to the over-all receive-only Earth station noise temperature should be limited to about 5°K. For an economic receiver design, a noise factor of 15 db (or 7500°K) is achievable and therefore the net gain preceding the receiver must be at least 32 db. This net gain includes the signal divider losses, which for a 12-way division are 11 db, indicating that the LNA gain required is 43 db. For as signal divider with only four divisions, the divider loss is 6 db and a lower gain LNA of 38 db could be employed. Regardless of the number of signal divisions, however, the net gain preceding the dual conversion receiver must be 32 db minimum so the receiver noise factor will not contribute more than 5°K to the Earth station system noise temperature.

For a minimum system C/T of -144 dbw/°K and a typical receive Earth station system noise temperature of 200°K (+23 db ref °K), the minimum received carrier level at the LNA input is -121 dbw. An Earth station system noise temperature of 180–200°K is obtainable with an uncooled LNA. The received carrier level at the dual conversion receiver input is then $-121 + 32 = -89$ dbw, minimum. This is applicable to a down link limited system, the worst case in determining the minimum dual conversion receiver input. It is interesting to note that the receive system noise temperature is essentially independent of the antenna diameter; therefore, for a given down link limited system C/T, the carrier level at the LNA input is also independent of antenna diameter (or antenna gain).

The basic design requirements of the dual conversion receiver are: carrier input level, -89 to -81 dbw; threshold bandwidth, 10–36 MHz; carrier deviation, 6–24 MHz peak-to-peak; and minimum carrier-to-noise ratio, 11 db.

The 8 db range of carrier input level is accommodated by the dynamic range of the amplitude limiter preceding the

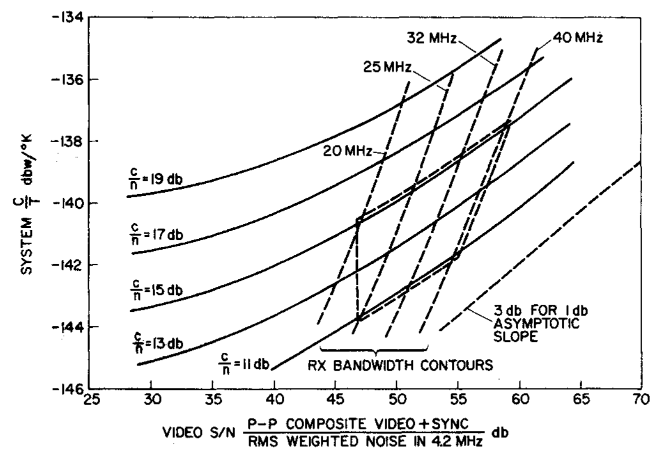
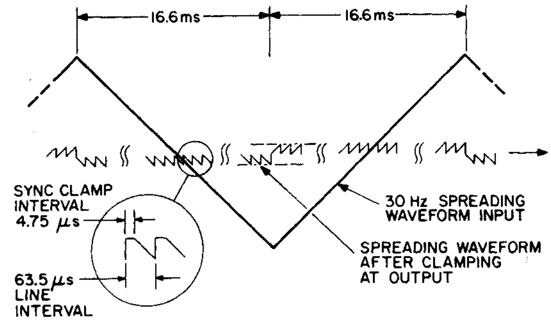


Fig. 2 C/T vs S/N for constant C/N and Carsons Rule bandwidth.



$$\text{EFFICIENCY} = \frac{\text{P-P INPUT}}{\text{P-P OUTPUT}}$$

$$= \frac{16600}{2 \times (63.5 - 4.75)} \text{ OR } 43 \text{ db}$$

Fig. 3 Spreading waveform removal—line by line clamping.

demodulator and by manual gain adjustment in the 70-MHz if amplifiers. The threshold bandwidth is set by interchangeable 70-MHz filters. The carrier deviation is adjusted by a gain control at the discriminator output and by inclusion of adequate baseband gain to deliver a 1-v video output with the lowest carrier deviation. The ability to operate with carrier-to-noise ratios down to 11 db is consistent with conventional demodulator design.

Receiver Signal Flow

A receiver design suitable to meet the system requirements outlined is shown in Fig. 1. The receiver is a dual conversion type employing a first if of 1112.5 MHz and a second if of 70 MHz. The receiver bandwidth at its input is 500 MHz from 3700–4200 MHz. The first if bandwidth is fixed at 40 MHz consistent with the maximum transponder or allocated bandwidths considered. The second if bandwidth can be adjusted by inserting the desired 70-MHz if filter bandwidth up to 36 MHz. This second if filter at 70 MHz primarily determines the receiver threshold bandwidth required for a specific system and is designed to be readily interchangeable with filters of various bandwidths from 10 to 36 MHz. The filtered 70-MHz if signal is then processed by an amplitude limiter and fed to a wideband frequency discriminator to recover the carrier modulation. The baseband signal level is adjusted to enable operation with the required range of carrier deviations and then raised to a fixed level by a video amplifier. The video amplifier provides two isolated outputs. One output drives the video path and the second output drives the 7.5-MHz audio subcarrier path. The video path signal is de-emphasized and filtered by a 6-MHz low pass filter to remove the 7.5-MHz audio subcarrier. The low pass filter is designed with a pole at 7.5-MHz, and about 70-db rejection of the audio subcarrier is obtained. The video signal is clamped by a sync-tip clamper amplifier that removes the triangular spreading waveform from the video signal output. The clamper amplifier has two isolated outputs and one is used as a video monitor; the other output is fed to the video/audio summing network. The audio subcarrier path signal is filtered by a 7.5-MHz bandpass filter to remove the video signal. The audio subcarrier signal is then level adjusted and fed to a dual output amplifier. One output is used as an audio subcarrier output monitor and the second output is fed to the video/audio summing network.

The summing network has low loss for the video signal and a large insertion loss for the audio subcarrier. With the level adjustment provided for the audio subcarrier, the output of the summing network is 1-v peak-to-peak video plus an audio subcarrier level consistent with standard terrestrial microwave systems. The multiplexed video/audio subcarrier signal can be fed directly to a terrestrial microwave system without the need for demodulation of the audio subcarrier if this is the means by which the information is to be relayed to the end user. As described, monitor outputs of both the video signal and—separately—the audio subcarrier are available for local monitoring of the performance at the Earth station. The multiplexed video/audio subcarrier signal is then fed to the baseband switch, which in the event of equipment failure can be derived from the protection receiver output.

Local Oscillator System

Tuning the dual conversion receiver to any frequency in the 3700–4200 MHz band is accomplished by changing the frequency of the first local oscillator. This first local oscillator consists of a 12-channel crystal oscillator and an automatically phase-locked microwave source. The tune frequency of the receiver is determined solely by choice of the plug-in crystal frequency and can be any desired frequency within the receiver bandwidth. No restriction of adjacent channel spacing is necessary. A 12-channel crystal oscillator was used, based on the normal allocation of 40 MHz per video carrier and therefore the limitation of 12 satellite channels in a nominal 500-MHz bandwidth. Selection of any of the 12 frequencies available is by means of a contact closure for the desired crystal frequency. The output of the crystal oscillator at approximately 100 MHz is then fed to the automatic phase-locked microwave source. This source consists of a basic voltage controlled oscillator (VCO) at nominally 1.3 GHz and an X4 multiplier to a first LO frequency 1112.5 MHz above the received carrier frequency; a first LO frequency range of 4812.5–5312.5 MHz. The source also includes a phase-locked circuit which locks the 1.3-GHz VCO to a multiple of the 100-MHz crystal reference frequency. In the event of loss of phase lock, or a change of crystal reference frequency resulting from a requirement to switch the receiver tune frequency, a search signal sweeps the 1.3-GHz VCO across the band until the 1.3-GHz VCO and the multiple of the new 100-MHz reference frequency coincide and phase lock is reestablished. The search signal then stops automatically. An alarm from the phase detector is used to mute the receiver during this search period.

The second local. oscillator used to convert the 1112.5 MHz to 70 MHz is a fixed tuned microwave source at 1182.5 MHz, also above the signal input to avoid inverting the carrier deviation sense at the 70 MHz output from that at the 3700–4200 MHz receiver input.

Receiver to Receiver Coupling

With many broadband receivers fed from a broadband signal divider, the coupling between receivers and the coupling of the first LO leakage between receivers via the signal divider must be considered. In this system all received carriers are fed to all receivers. Therefore, any receiver will find at its input the desired signal, and also many other lower level and delayed components of the same signal due to reflectors of this signal from other receivers coupled via the signal divider. This introduces delay and amplitude ripples into each receiver output. Similarly, LO leakage from each receiver's first mixer will be coupled to all other receivers, and, depending upon the converter conversion efficiency under these conditions, an undesired carrier can be converted to the fixed 1112.5 MHz if by the leakage of the appropriate undesired LO signal. To maintain these effects at an insignificant level, the requirements for coupling loss from one receiver mixer to another receiver mixer can be determined based on the characteristics of the mixers and LO levels employed. This has been evaluated and a net loss of 55 db minimum is required. This requirement is met through use of doubly balanced mixers, high directivity couplers in the signal divider, and ferrite isolators at each receiver input. The design of the signal divider is, however, an integral part of the dual conversion receiver design.

First if Frequency

The choice of the first if frequency at 1112.5 MHz is made after consideration of the dual conversion receiver input tuning range and mixer intermodulation products. The actual frequency used, 1112.5 MHz, is one-half the satellite translation frequency of 2225 MHz required to convert the up link 5925–6425 MHz band to the down link 3700–4200 MHz band for presently planned commercial satellites.

By setting the receiver first local oscillator at 1112.5 MHz above the input carrier, the first local oscillator circuitry, including the crystal reference oscillators, can be used directly in a companion dual conversion transmitter. The image of the receiver is then the transmitter band, but with such a frequency separation of 2225 MHz, a large image rejection can be obtained by a single fixed tuned 500-MHz wide bandpass filter at the signal divider input.

The first mixer and input isolator are the only components required to operate in either the 3700–4200 MHz or 5925–6425 MHz band. These are available with close to an octave bandwidth and therefore essentially all rf components of the dual conversion receiver and companion dual conversion transmitter are interchangeable.

Spreading Waveform Removal

A sync-tip clamper is used to remove the 30-Hz triangular spreading waveform from the video output of the receiver. This technique clamps the video signal and spreading waveform to the reference point during each sync interval. The residue spreading waveform is therefore a triangular waveform at the line rate, as shown in Fig. 3. The clamper efficiency is 43 db. For a system using about 20-MHz peak-to-peak video carrier deviation, the typical spreading waveform deviation used is about 2 MHz peak-to-peak; a ratio of 20 db. After pre-emphasis of the video signal at the transmitting station, the low-frequency video deviation is reduced by 10 db. At the receiver, after de-emphasis, the ratio of the video signal to the spreading waveform signal is 10 db. With a clamping efficiency of an additional 43 db, the ratio of the peak-to-peak video signal to the peak-to-peak residue spreading waveform is 53 db for the system parameters illustrated. The use of a clamper for spreading waveform removal has the advantage of also clamping out other low-frequency noise or hum from the video output signal. The clamper retains its theoretical efficiency for spreading waveform levels equal to the video level.

Audio Subcarrier

A conventional subcarrier technique at 7.5 MHz is a method of transmitting the TV audio information on the same rf carrier. The minimum carrier deviation due to the audio subcarrier can be set so that the audio channel and receiver thresholds coincide. However, it has been found by experiment that the video-to-audio crosstalk can be improved by further increasing the carrier deviation resulting from the audio subcarrier. The optimum level is dependent upon other factors such as the system phase and amplitude linearity. It has been found experimentally that with a lower frequency subcarrier at 6.17 MHz, the video-to-audio crosstalk is considerably worse than with a 7.5-MHz subcarrier. This is particularly noticeable when performing video tests with test pattern generators. At 7.5 MHz the crosstalk is tolerable. The use of a higher frequency subcarrier such as 8.2 MHz requires additional carrier deviation to keep the receiver and subcarrier thresholds coincident.

The use of the subcarrier technique is a practical method, at least for the large receiver bandwidth systems, and avoids the use of separate rf carriers and receivers to transmit the audio information. The baseband protection switching is also simplified since the video and associated audio subcarrier can be switched simultaneously by a single switch element. Tests have shown that the video-to-audio crosstalk does not degrade the demodulated audio signal-to-noise below 55 db while the audio-to-video crosstalk is not perceptible on a video monitor.

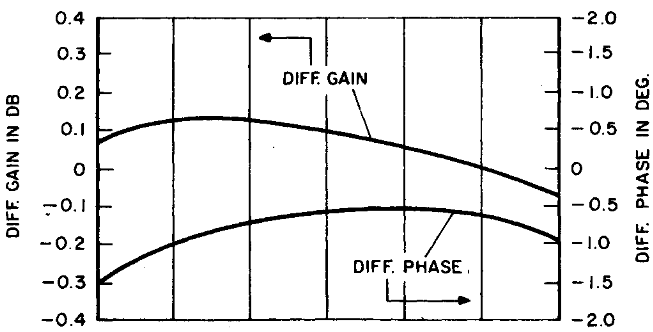


Fig. 4 Differential phase and gain.

IV. Protection Switching

As shown in Fig. 1, the protection channel dual conversion receiver is identical and interchangeable with other receivers. The interface and control of the system is made at the control unit. Information to determine the operating frequency of each receiver is fed to the control unit in a 4-bit parallel binary code. This data is processed and stored for future use by the protection channel receiver. The output of the logic is decoded and frequency information is fed to the receiver in the form of 12 control lines, one for each of the 12 possible frequencies.

To determine receiver status, monitors of first local oscillator phase lock, received carrier level, and spreading waveform presence are derived from each receiver and combined to provide a receiver status alarm. The spreading waveform is used as the equivalent of a continuity pilot indicating the presence of carrier modulation.

Upon failure of a receiver, the protection channel receiver is switched to the operating frequency of the failed receiver and its status determined. If the status is normal, the baseband switch operates to route the output of the protection channel receiver to the normal receiver output interface with the terrestrial facility. If, for example, the transmitting station is radiating a carrier but the modulation is not present, then the status of the protection channel will not be normal due to absence of spreading waveform signal and the baseband switch will not operate. The fault in this example is not at the receiving Earth station. Under these conditions the protection channel receiver remains available to protect other receivers in the event of their failure.

Another alarm status, derived from the sum of all carrier monitors and spreading waveform monitors, is used to indicate probable failure of the on-line LNA common to all receivers. This alarm is used for automatically switching the redundant LNA into service. Manual control of the logic is available for maintenance at the Earth station. The control logic interface is compatible with many standard supervisory and control systems for remote operation of the unattended Earth station.

V. Test Data

Measurements have been made on a receiver as described and some of the important transmission characteristics are presented. The data was measured with a carrier deviation

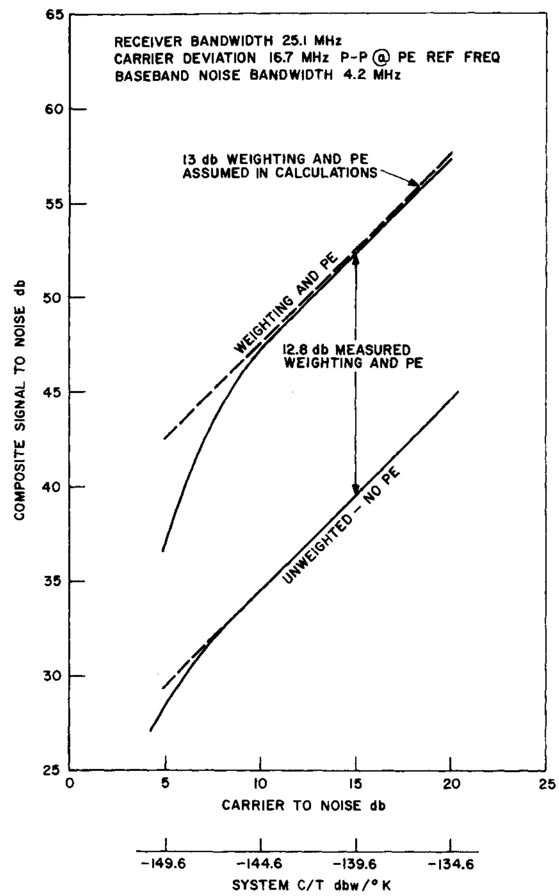


Fig. 5 Receiver threshold characteristic.

of 24 MHz peak-to-peak at the PE reference frequency and with a receiver bandwidth of 32 MHz. These conditions represent close to the maximum used bandwidth system and are similar to those proposed in Ref. 2.

The effect of the total receiver group delay, including the conventional demodulator, is to introduce differential phase on the color subcarrier. Figure 4 shows the measured data at 50% APL, including a spreading waveform deviation of 2 MHz peak-to-peak. The differential phase shown is about 1°. Measurements have also been made with 10–90% APL using a vectorscope, and about 1.5° of differential phase was observed. Further equalization of the group delay and resulting differential phase is possible.

The differential gain measurement, shown in Fig. 4 as 0.25 db, is primarily due to the linearity of the demodulator. The measurements shown, although made on only the dual conversion receiver, have also been made including an LNA with very similar results. This is expected based on the group delay characteristics of current broadband LNA, which are essentially transparent when compared with the 32-MHz band limited receiver. The major type of group delay introduced by an LNA in any 40-MHz bandwidth is ripple, with typical periods of 20–50 MHz. This particular characteristic of the LNA must be carefully controlled or limited because when the receiver is to be switched to various operating frequencies in the rf band, some variations in differential phase will be expected that cannot be equalized by a fixed equalizer in the dual conversion receiver.

The minimum operating carrier-to-noise ratio expected is 11 db. This enables the use of a conventional demodulator with a threshold of about 10 db depending upon the definition of the threshold point. Measurements have been made of the demodulator threshold characteristics; these are shown in Fig. 5. The figure shows both the calculated performance and the measured characteristics. The receiver bandwidth was accurately determined as 25.1 MHz in the test setup. Figure 5 shows the flat unweighted noise in a 4.2-MHz bandwidth and also the monochrome weighted and deemphasized noise in 4.2-MHz. The net weighting effect of monochrome weighting and deemphasis is measured as 12.8 db. As will be noted, the weighting assumed in the calculated performance was 13 db.

In the threshold area of around 10 db carrier-to-noise, the unweighted flat noise in 4.2 MHz exhibits the soft threshold characteristics to be expected because the noise power is predominantly at high end of the baseband of 4.2 MHz. However, the weighted and de-emphasized noise exhibits a more defined threshold due to the rapid increase of the noise at the lower end of the baseband, as the carrier-to-noise ratio is reduced, and the attenuation of the high end of the baseband noise by the de-emphasis characteristics and monochrome weighted network.

This effect is shown in Fig. 6, where the weighted deemphasized noise in 4.2 MHz is shown. The distribution of the noise per 4-kHz bandwidth is shown for various carrier-to-noise ratios. The change in spectral distribution results from impulsive type noise predominantly at the lower end of the baseband, where under large carrier-to-noise ratios, a large FM improvement is obtained. As the threshold is approached, the FM improvement is lost, and the noise level approaches that of an amplitude modulated system.

The noise has been observed and indications of high impulses are present. It is considered, therefore, that the measured broadband weighted and deemphasized noise in 4.2 MHz may not be representative of the picture quality because of the probable high interference effect of the noise impulses. It is reasonable only to assume that, from the measured data, a safe minimum operating carrier-to-noise ratio is 11 db in order to avoid excessive impulse noise.

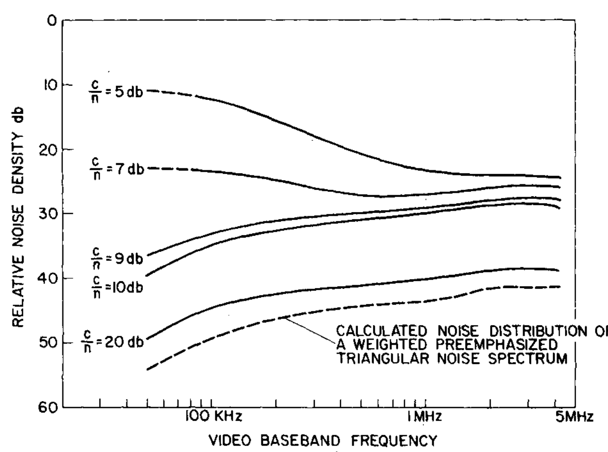


Fig. 6 Noise density per 4-kHz bandwidth.

VI. Summary

A receiver design has been described which will operate with any of the system parameters within the assumed range. The performance and system parameters have been calculated and presented so that for a given system C/T, the optimum carrier deviation, receiver threshold bandwidth, and video signal-to-noise can be determined—or vice versa. Measured data is shown to verify these calculations and also, the characteristic of the video signal-to-noise vs carrier-to-noise ratio in the receiver threshold region. The use of a 7.5-MHz audio subcarrier for transmission of the TV audio has been found to be practical for some systems. Some aspects of the equipment redundancy and protection switching have been covered based on the requirement to design a reliable unattended Earth station. The Earth station described will interface with standard terrestrial equipment systems and levels for both the transmission of the video-audio signals to the end user and the supervision and control of the unattended Earth station.

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Project Delphi—Technical Aid to the Developing Nations by Consulting Services Satellite

R. G. PAY*
TRW Systems Group, Redondo Beach, Calif.

Lack of skills and emigration of available skills are formidable obstacles to economic growth in developing nations. To see if space technology can help overcome these obstacles, mission requirements for enhancing international technical cooperation in the United Nations Second Decade of Development were examined. This led to a preliminary feasibility study of a satellite video-telephone system serving 9000 experts in developed and developing nations by 1980. A model of a one million square-mile developing region containing seven nations, 10 centers of excellence, and 70 field centers was assumed. Each of four such regions could be served by a 12-GHz, 3500-lb synchronous satellite with a solar array power of 12.5 kw. Each satellite also would link its developing region to two advanced centers in developing nations. The most difficult problem is obtaining adequate allocation of the synchronous-orbit spatial/spectra resource for the developing nations.

Introduction

A NUMBER of space systems has been identified as potentially useful to the developing nations: communications satellites, weather satellites, resource survey systems, educational television systems, etc. However, most of them are impractical until some solution to the shortage of technical skills and low product output in developing nations is found. In 1967, two-thirds of the world's population lived in countries where the per capita output was less than $100 per year.[1] Roughly half of the developing nations that are members of the World Bank have a growth rate of 1% or less.[2] Furthermore, the growth goals of the United Nations Second Decade of International Development of 3.5–4.5% in per capita income[3] are suspect because they depend on the advanced nations investing 1% of their own GNP in economic aid, a target missed by a wide margin in the First Decade of Development.

A "Consulting Services Satellite" would make available aid more effective by providing a two-way television link between personnel at field and regional centers in the developing nations and consultants at institutions in the advanced nations. This approach would be consistent with the trend that has been appearing towards the end of this decade; e.g., whereas the United States AID program declined a total of $250 million in economic assistance in 1967, the total for technical cooperation was slightly higher than the previous year.[4] Similarly, the U.N. Development Program, which is largely concerned with technical assistance in the early phases of projects, has shown a steady growth in the latter half of this decade, reaching $200 million in 1969.[5] It also has been suggested that science and technology "will have to become one of the major preoccupations of the United Nations, and the stimulation of the transfer of technology one of its principal actvities."[6] However, there is a growing shortage of experts that can provide assistance, and the problem is aggravated by a net flow of skilled personnel from the developing nations to the advanced nations. Between 1949 and 1964, 73,500 scientists and engineers established permanent residence in the United States, and in the latter part of this period Asia and South America were contributing 27% of this flow.[7] Moreover, training programs in the developing nations will fall short of the need for technical and scientific personnel by tens of thousands, if satellites are used extensively there for meteorology, communication and education,[8] and other proposals, such as nuclear reactor projects for bringing water to desert areas, would make similar demands on meager reservoirs of skill.

A New Work Environment

To encourage skilled people to stay in their own country and to encourage the ones who have emigrated to go back, a new climate has to be created. The Consulting Services Satellite (CSS) could revolutionize the environment and work of people in the developing nations. What is often needed is "intermediate technology"[9,10] rather than advanced technology. Furthermore, important elements to be transferred are the research and educational methods and attitudes of the West—"with their emphasis on problem solving through experimentation, analyses and tests, and their objectivity,

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* Manager, Development Planning, Science and Environmental Systems Operation, Space Vehicles Division; now at Aerospace Corporation, El Segundo, Calif.